Executive Summary

Flight Operations has been very efficient in maintaining the health and safety of the spacecraft and collecting the large amount of recorded science data. Attrition has been high, affecting all areas of the Flight Operations Team (FOT), but the valuable knowledge has been retained through many online databases and procedures. This has been highlighted with the refining of the Certification and Training program and implementation of advanced contingency training. Continuous Risk Management (CRM) has been common practice, and though some minor incidents have occurred, Configuration Management (CM), internal automation scripting, and a high-fidelity simulator have kept operations safe, efficient, and constantly improving. Software releases and the redesign of the Mission Operations Center (MOC) to a three-server configuration have provided a much more robust ground system, and aided in the accomplishment of 99.45% data capture. Preparations are underway to meet future challenges of the 6.4-year mission (current prediction), such as another Leonids Storm and the Year 2000 (Y2K) transition, with the same high quality of operations and customer support.

The Observatory has performed very well, with no major anomalies. It has transitioned to Sun Acquisition twice and Low Power once, though not due to actual failures. A higher-than-expected temperature on the -Y Solar Array (SA) drive prompted investigation into parking the array, but resulted in only limiting the tracking scenario. A ‘jitter’ was

observed in the gyro data, which resulted in a modification of the SA tracking algorithm. The Earth Sensor Assembly (ESA) displayed possible fogging, but has settled within safe limits. Yaw updates have displayed large seasonal increases, and has exceeded 1σ control limits at times. Two Delta-V maneuvers have been aborted, due to tight limits, and the thrusters are performing more efficiently than predicted with some off-modulation for small Pitch and Yaw disturbances. Irregular behavior has been experienced with one of the battery cells, but it has not effected operations. A software fix may be required for several non-intrusive code flaws in the Power System Interface Bus (PSIB) logic. The transponder frequencies have settled within the communications threshold, and signal problems have been minimal. The optical busses are behaving as predicted in the atmospheric conditions, and Frequency Standard (FS) B is showing no signs of failure.

The instruments have been performing well and collecting great science data. They have been powered off four times, due to contingency execution and the Leonid Storm of 1998. The Clouds and Earth's Radiant Energy System (CERES) has been greatly hindered by a failing voltage converter, but has participated in numerous ground campaigns for science coordination. Routine resets are performed on the Lightning Imaging Sensor (LIS) to clear data sequence drops, though no data has been lost. The frequency agreement for the Precipitation Radar (PR) expires at the end of 2000. A Deep Space Calibration was performed to isolate interference in the TRMM Microwave Imager (TMI) data. Outgassing of the Visible and InfraRed Sensor (VIRS) has been successful in clearing thermal shorts experienced during contingency and Deep Space Calibration events.

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1. Document Overview

This is the *Tropical Rainfall Measuring Mission (TRMM) 18-Month Performance Evaluation Report*, and is the first published report for distribution since the *TRMM 60 Day In-Orbit Performance Evaluation Report*. The 60 Day Report contains information from Launch in November 1997 through the end of checkout activities in January 1998. The 18-Month Report documents the Observatory status and activities from January 1998 through June 1999. These two documents present a comprehensive overview of the Tropical Rainfall Measuring Mission to date.

This document is divided into five sections, with seven appendices for supporting documentation. Section 2.0 describes the Flight Operations strategies and activities, covering a broad range of topics. The section includes an operations overview and summary, the staffing philosophy and status, the training and certification plan, real-time and mission planning activities, the trending and analysis strategy, and external interfaces. Section 2.0 also contains information on the continuous risk management methodologies and examples, and key upcoming events, such as the Leonid meteor storm and the year 2000 rollover (Y2K). Ground System operations are discussed in Section 3.0, and include topics on major hardware and software changes and upcoming issues, such as the Y2K status of the Mission Operations Center (MOC). Section 4.0 describes the overall system performance of the Observatory, covering each subsystem individually. Section 5.0 similarly describes the overall performance of each of the five instruments.

The seven appendices contain the supporting documentation for the various topics discussed in this report. Appendix A contains a summary list of the written Anomaly Reports (referenced throughout as ‘Anomaly #’). Appendix B contains a summary of the written Event Reports (referenced throughout as ‘Event #’). Appendix C lists the Generic Late Acquisitions recorded. Appendix D summarizes the Flight Software (FSW) Configuration Change Requests (CCR). Appendix E contains the summary list of all the spacecraft table loads. Appendix F contains the extra supporting plots, graphs, and tables that are referenced in the subsystem and instrument sections. Appendix G contains the Acronym List.

Unless noted, all times are Universal Time Coordinated (UTC)/ Greenwich Mean Time (GMT).

1.1 Introduction

The spacecraft Launch and In-orbit Checkout (L&IOC) operations went exceptionally well, and there were no significant problems with any Observatory components or instruments. Since that time, the TRMM mission and flight operations have continued to experience considerable success, and have even inspired a follow-on mission which is currently scheduled for launch in 2006. Operationally, there have been only four interruptions to science data collection since January 1998. There were two events which safed the spacecraft and powered off the instruments due to on-board constraints which were designed too conservatively. A third event was a low power load-shed condition which resulted from an attempt to characterize a battery cell's unusual behavior. The fourth event was an intentional load-shed conducted as a precaution to the Leonid Storm of 1998. Of the five instruments on-board, only the Clouds and Earth's Radiant Energy System (CERES) instrument, which was added as a protoflight model, has experienced any serious problems. All instruments, including CERES, have met, or are expecting to meet, all of the science objectives.

2. Flight Operations

The mission has experienced considerable operational success over the first 18 months of science operations. For the nominal mission, TRMM orbits the earth with a 91 minute period and 35° inclination to the equator. A typical orbit approximates 354 x 348 km. Since the mission is such a low earth-orbiting mission, orbit boost maneuvers are performed every three to six days, as solar and atmospheric conditions require. In addition, 180° Yaw maneuvers are performed approximately once per month in order to keep the +Y side of the spacecraft out of direct sunlight. The instruments produce a high volume of data, and as a result, science data collection requires frequent contacts in order to continue the recorder operations without overflows. A typical 24-hour day consists of 15 to 18 twenty minute Tracking and Data Relay Satellite (TDRS) events, with the nominal 2048 kbps science downlink rate. A non-coherent event is performed once a day with the prime transponder in order to trend the frequency behavior. Similarly, a low-rate non-coherent event is performed on the backup transponder three days a week using the Omni antennas. Absolute Time Sequence (ATS) loads and Extended Precision Vectors (EPVs) are uplinked daily to handle on-board operations and orbit propagation. Table 2-1 below contains some important metrics in the operations and subsystem performance categories.

TRMM Operations Performance Summary	
Realtime Events Supported (approx)	9860
Generic Late Acqs Performed	33
Delta-Vs Supported	107
Yaw Maneuvers Supported	26
Orbits Flown	9147
Anomaly Reports Generated	74
Event Reports Generated	106
CCRs Generated	54
TRMM Spacecraft Performance Summary	
Fuel Remaining	716.85 kg
Sun Acq Events	2
Low Power Events	1
Safehold Events	0
Data Capture VR1	99.812%
Data Capture VR2	99.653%
Data Capture VR3	99.411%
Data Capture VR4	99.398%
Data Capture VR5	99.423%
Data Capture VR6	99.004%

Table 2-1 TRMM Performance Summary through June 1999

2.1 Staffing

The Flight Operations Team (FOT) is currently comprised of 15 people. Of these, four are Systems Engineers under the direction of an Engineering Technical Lead. There are eight Console Analysts plus a Mission Planner (MP) and a Manager. An Operations Supervisor slot is temporarily vacant, but will be filled through an internal promotion. This position will provide increased flexibility in that the responsibilities have been modified to support both the real-time and mission planning areas. The team also plans on pursuing a ninth console analyst per an overstaffing arrangement.

Flight team staffing can be characterized as an extended period of quiescence flanked by two periods of flux. In the March-May 1998 timeframe, five members left to pursue other opportunities. This was especially noteworthy since the Manager, Technical Lead, and MP were among the five. The Lead slot was filled internally while the Manager and MP slot were filled by experienced persons from other missions. Real-time console coverage was particularly stressed since two people are required in the 24x7 environment. While the support of the LANDSAT FOT (then in pre-launch) was utilized, the majority of this work was accomplished internally. The training program at TRMM, which encourages cross-training, proved itself quite valuable during these transition periods.

By May 1998, this initial flux situation abated with staffing conditions generally stabilized until May/June 1999, when the Manager and three experienced Console Analysts left the team. The Manager slot was filled internally, while three replacements were hired for the console slots. These three have begun their education into the operational workings of the spacecraft and ground system. Fortunately, the systems engineering staff has remained intact and with it the high level of technical expertise.

While many skilled, knowledgeable personnel have been lost, a large store of this knowledge and expertise has been retained. This knowledge is being passed along to the newer members. The emphasis on risk reduction, which is placed on operations, has led to a robust training program. It has proven effective in reducing the impact of the turnover rate. Therefore, the FOT will continue to function with the knowledge and professionalism needed to overcome future trials.

2.2 Certification and Training

In the flight operations environment, a proven certification and training program is essential for maintaining the skills and knowledge necessary for continued success. At TRMM, the Lead Engineer is responsible for the overall training and certification of the personnel. However, these responsibilities are further divided such that one of the subsystem engineers is also the lead for ensuring subsystem and advanced training skills are accomplished, and a senior Console Analyst is responsible for all real-time console training. Because attrition is a reality on any mission, the training program encourages and supports cross training, once the required skills are achieved. The goal is to have all members officially certified to operate as a Console Analyst, including the MP and engineering staff, to help reduce the impact when one or several people leave within a short timespan. Similarly, several of the engineering staff and shift personnel train on fundamental mission planning skills. The complete training program will be documented in the *TRMM Training and Certification Plan*, due out in August 1998.

The principles of continuous risk management are an integral part of the training program. One example is the quarterly review of the on-line certification tests. The FOT engineers periodically review the questions pertaining to their respective subsystems and decide if there have been any operational changes or acquired knowledge which might improve the tests. Similarly, any out-of-date question is removed from the active database. The real-time and offline skills checklists are also periodically reviewed to ensure they are kept current. Feedback is also encouraged to determine the effectiveness of the questions and improve the learning process. Official certificates are provided for accomplishing the Console Analyst, Spacecraft Analyst, and advanced training requirements, to help provide both focus and morale for employees.

Implementation of an advanced training program has begun, in which all team members will participate annually. Once members have passed the various on-line certification tests and skills checklists, the next phase of their training includes access to a library of telemetry playbacks for anomalous or rare events, as well as simulations involving anomaly identification and resolution. These incorporate the failure identification and recovery checklists which were developed for potential failures, such as a failed Solar Array (SA) drive or autonomous Gimbal and Solar Array Control Electronics (GSACE) switch. In addition, the Console Analysts are assigned backup responsibility to the engineering staff for the spacecraft subsystems or instruments of choice, especially for reports or trending projects. This provides more one-on-one mentoring with the Systems Engineers and allows for a better understanding of the spacecraft, and a better trained team as a whole.

2.3 Real-time Activities

TDRS events are taken approximately once per orbit by the Console and Spacecraft Analysts. The real-time personnel are primarily responsible for the health and safety of the spacecraft and the accounting for all downlinked data. Occasionally, command requests initiated by the Systems Engineers, or outside sources such as instrumenters or the Applied Engineering Technology Directorate (AETD) engineers of the National Aeronautics and Space Administration (NASA), are carried out by direction of the Spacecraft Analyst. Each request is electronically generated to avoid mistakes in misreading handwriting. If the command request requires a Transportable Payload Operations Control Center (TPOCC) Systems Test and Operations Language (TSTOL) procedure, the procedure is printed out with the correct choices circled and attached to the request.

Prior to each real-time event, a TSTOL procedure automatically (once manually started) configures the MOC ground system for the upcoming support. The Local TPOCC Switch (LTS) lines must be configured manually by the FOT who are also responsible for setting the countdown clock using the times from the Confirmed Events Schedule (CES). There has been one incident during the course of the mission when the countdown clock was set incorrectly and an event was not supported (Event #75). The procedure for taking events has since been changed by having both Analysts verify the countdown clock.

Commanding is performed on string 1, with string 2 used as a hot backup. This provides a sufficient failover option in the event of a string failure. However, the MOC currently does not have a sufficient backup for catastrophic events such as a fire in the building. Under the original operations concept, the Special Operations and Testing Area (SOTA) in Building 14 would have been used as a backup in the event that Building 32 became unavailable. Unfortunately, in the Fall of 1998, the SOTA was permanently dismantled, eliminating facilities redundancy.

A typical real-time event consists of verifying the forward by sending a no-op command and then performing data storage activities using approved TSTOL procedures. All pertinent information about the event is recorded in its respective pass plan. Due to the small on-board recorder space and tight time constraints, there is occasional data loss. For exact times of these data losses and reasons, see Appendix F. See the Flight Operations Overview section for percent data capture since launch.

Following each real-time event, the console personnel run a TSTOL procedure to bring down the ground system in a graceful manner, closing history files and creating delogs of the event. A script is also run to send command history files and snap files through the Flight Dynamics Facility (FDF) Orbital and Mission Aids Transformation System (FORMATS) to the TRMM Science Data and Information System (TSDIS) and Langley Research Center (LaRC). The FORMATS event screen is monitored a few times during a shift to verify successful transfers.

A Switching, Conferencing, and Monitoring Arrangement (SCAMA) loop provides critical voice interaction with external interfaces during a real-time event. The FOT communicates with the Communication System Controller (CSC) at the White Sands Complex (WSC) before, and sometimes during, events to brief of event parameters and in troubleshooting any problems, such as late acquisitions. The loop also provides a link to the Network Control Center (NCC) Performance Analyst (PA) and the Conversion Device (CD) and Communications (Comm.) Managers for troubleshooting line problems and possible event conflicts. There is also a Closed Conference Loop (CCL) that provides direct voice communication with the Packet Processor (Pacor) II facility. This line has proven to be quite useful during some events to determine if all data was recovered.

A spacecraft ATS load is uplinked daily, which primarily contains commands to start Acquisition of Signal (AOS) and Loss of Signal (LOS) sequences for all TDRS events of the following GMT day. It also contains a command to switch to the next day's load, as well as a call for a safing Relative Time Sequence (RTS), in case commanding is somehow lost. These loads are verified by 2 engineers, the MP, and the Console Shift Lead, using a proven, thorough checklist. Due to other activities, such as Generic Trending and Analysis System (GTAS) trending performed by real-time personnel, certain duties can sometimes be overlooked. On 98-172, the daily ATS load was not loaded (Event #41). At the end of the day the safing RTS, which is normally aborted via an abort command contained in a new load which is active in the opposite buffer, fully executed, configuring the spacecraft to a low data rate mode and placing CERES in Safe mode. This problem was corrected by improving the shift handover log and making better use of reminder dialog boxes, which appear on the prime commanding string computer screen several hours before the end of the GMT day.

A TRMM EPV load is uplinked to the spacecraft daily, except on days of Delta-V maneuvers (Delta-V command includes EPV parameters to match post-burn altitude), to begin propagating at 20:00. An EPV for each of the four TDRSs (TDE (East), TDS (Spare), TDW (West), and TD171 (TD7)) are loaded approximately once per month.

Delta-V maneuvers are performed every 3 to 6 days to keep the spacecraft in a frozen orbit. For each Delta-V, a command file is uplinked, and the appropriate RTSs are enabled. There has been only one time, during the early part of the mission, where the RTSs were mistakenly not enabled (Event #35). The mistake was noticed before the burn and both sides of the Catbed Heaters were powered on to warm the thrusters faster (see the RCS section). After analyzing the problem, the FOT streamlined the process by making better use of configuration monitors and adding comments to the pass plan, such as specific RTSs to be enabled.

Prior to each real-time burn, a Delta-V subset file is also opened to assist in trending pressure, temperatures, and 8 Hz telemetry. During Delta-V maneuvers, the real-time personnel are responsible for dumping the thruster log table after each burn, to later send to FDF.

Prior to the end of the shift, history files containing playback engineering data are transferred manually to a 4 GB disk for storage and then deleted from the Front End Processor (FEP). At the end of each shift, the new crew is briefed using a handover log. The log has a checklist of tasks performed daily or weekly, such as backups and verifying the LTS lines. It has also has room to write all pertinent information regarding each event and an additional note section. It is required that the incoming crew understand the handover before both shifts sign the log.

Once a day, a report is generated containing the total duration of time spent taking events for the GMT day and is sent to the Operations Support Center (OSC), via fax. A daily

Ops summary is also generated containing a status of the spacecraft and ground system and then distributed to the Mission Director (MD).

2.4 Mission Planning

Mission Planning consists of several activities performed on a daily or as necessary basis. The MP will schedule sufficient supports via the Space Network (SN), build command loads required for operations, interface with various support groups and the Systems Engineers, and maintain the Oracle database (back-ups), as well as build and maintain support files (Configuration Codes) and command sequences (RTS and MACRO). Flight software loads are generated, tested, and delivered by the FSW of Code 582. This report time frame saw only occasional edits or updates to the above mentioned files/sequences. However, scheduling and load generation is a daily activity. The MP uses various software systems including the User Planning System (UPS), Oracle, Mission Operations Planning and Scheduling System (MOPSS), Guide Star Prediction and Occultation (GSOC), and FORMATS packages. In addition to the daily interface with NCC Scheduling (via UPS), mission planning also receives daily files from FDF for ingest into MOPSS and Oracle so that the various loads can be built.

2.4.1 Load Generation

Command loads (ATS & EPV) to the onboard Spacecraft (S/C) and Attitude Control System (ACS) processors are generated daily and uplinked to the spacecraft. Patch and Delta-V loads are generated as necessary and uplinked to the respective processors. Daily command loads are only built after the latest FDF position files have been ingested. The FOT prefers to stay two days ahead for daily ATS command loads. EPVs must be generated daily unless a Delta-V maneuver is to be performed: an updated vector is contained in the burn command (Delta-V load). Delta-V loads are generated from FDF provided input and are uplinked approximately every 3-6 days. Containing nine commands, the appropriate thruster package is fired in relation to the correct flight direction. Patch loading is performed on an as-needed basis and is used to update an on-board ATS load. Changes to RTS and MACRO command sequences are performed in conjunction with the various engineers and science teams, using the Mission Operations Change Request (MOCR) process (see section 2.8). The RTS loads are tested with the Software Test and Training Facility (STTF) simulator prior to approval. Once approved, they are uplinked to the spacecraft and otherwise recognized by ground system software. At no time has the mission been jeopardized for lack of a command load.

In April 1998, several commands from the Safing Sequence of the daily ATS load executed (Event # 25). Executing at the beginning of the GMT day, it turned off transmitter 1, turned on transmitter 2, and placed the CERES instrument in a safe condition. Subsequent investigation revealed that the Safing Sequence MACRO had been mistakenly expanded when this daily load was regenerated. Instead of one command call (the RTS itself), all the commands of the safing macro were placed on the MOPSS timeline. This was discovered, and most commands were deleted, but several were missed. In response to this incident, the daily load checklist was improved to ensure similar problems would not be repeated.

There have been several other additions and/or modifications to command sequences and procedures. In June 1998, RTS #2 was modified and RTS #13 was created. Low power Standard Power Regulator Unit (SPRU) commands were removed from RTS #2 and placed in RTS #13 (see Power Section). In July 1998, scheduling rules for the CERES Alongtrack operation were modified to automatically add commands to the timeline. This time consuming process had been done manually since the inception of Alongtrack ops in April 1998. In September 1998, an enhanced process of scheduling Visible and InfraRed Scanner (VIRS) Solar Calibrations was implemented along with RTS #34, which turns CERES off. The call for RTS #120 (DVINIT), Catalyst Bed Heaters On, was changed from 91 to 45 minutes prior to the first burn of any Delta-V maneuver in May 1999. A new command MACRO was created to reset Telemetry & Statistics Monitors (TSMs) #4 and 7 (used to monitor Solar Array (SA) tracking). This MACRO was made operational and executes from every daily ATS load at 23:58:00.

Y2K testing of the mission planning software began in March 1999. At this time, the daily operations shifted string 2 (backup) from string 3 (prime), where it currently remains. Further testing took place with the NCC. While the test rollover time was missed, post rollover testing of events using actual configuration codes went well.

In May 1999 an e-mail request (the usual method for both the Precipitation Radar (PR) and VIRS) for a PR External Calibration was overlooked (Event #102). The customer was informed and a replacement was included on a subsequent ATS load. The Continuous Risk Management (CRM) process was used to ensure that a similar incident could not be repeated. Now, the daily calendar is updated whenever a request is received, and the daily load checklist has a reminder to check this before approving a load.

2.4.2 NCC/TDRS Scheduling

The NCC provides scheduling and real-time service in support of the Space Flight Tracking and Data Network (STDN) also known as the SN. Scheduling of TDRS time has become more flexible with the use of four of the available TDRSs: TDE, TDS, TDW, and TD171. Conflicts are generally minimal since the upgrade to the Multiplexer/Demultiplexer (MDM) bandwidth at WSC in May 1999. During previous Space Transport System (STS) flights, bandwidth conflicts with the various users were a major problem to missions which demand a high telemetry downlink rate.

The SN has had other changes in the timeframe of this report. In February 1999, the new NCC 98 software upgrade was made operational. A software patch was subsequently delivered in June 1999 (99-172). There was also a new release of software to the UPS, which is the scheduling tool used to obtain TDRS support. This UPS upgrade is compatible with NCC 98 and Y2K compliant. Several scheduling problems have occurred since these upgrades were installed. A reduced response time is the most general, although there have been cases where events, deleted from the MOC schedule, remain active in the NCC and WSC systems (see Event #96 and 110). As a result, these events are not included in the daily spacecraft load while the SN shows them as active. NCC or WSC personnel must manually delete these events. The problem remains under investigation.

Circumstances periodically force changes to the active schedule which must be resolved promptly. There have been instances where SN events were lost to a higher priority mission, to critical S/C activity, or to a equipment failure at WSC. While the project realizes that these things can and will happen, they usually involve additional changes to the daily command load. Rebuilding a daily spacecraft load, or generating and uplinking a patch to an active load, presents added risk. Procedures and checklists have been developed to minimize the risk associated with deviations from nominal operations. For example, in October 1998, a problem with TD171 forced the cancellation of all of its support activities for an entire day. The FOT then had to schedule replacement events, change and uplink the spacecraft load, and perform several blind acquisitions. Despite the outage, all science data from this period was recovered.

Now that the problems have been identified, the interaction with the SN has been routine and generally trouble-free during the majority of this time period. Normally, 15-18 events are scheduled per day and conflicts are minimal. The MP works with the NCC counterpart to resolve scheduling problems in a timely fashion. This relationship has been, and continues to be, professional and productive.

2.5 Offline Trending and Analysis

The Generic Trending Analysis System (GTAS) continues to be a reliable and useful system to Operations. The GTAS system has the capability to store hourly and daily statistics for the life of the mission. These statistics are quite useful in understanding seasonal and solar beta angle variations on various spacecraft components. It also helps identify trends that may become potential anomalies.

Each night, a Level-0 Processing (LZP) file, containing the 24 hours of housekeeping data from the previous day, is delivered from the Data Distribution Facility (DDF) via a File Transfer Protocol (FTP) utility called Consim. The Science Data Processing Facility (SDPF) poller automatically takes this file and performs subsetting on selected trending mnemonics. These subset binary files are then ingested onto a hard drive. A power analysis report, plus hourly and daily statistics, are generated using the data from the LZP file. Each week, plots are generated using the hourly statistics for review. Mission life plots are also updated monthly.

Plots of Delta-V and Yaw maneuvers are also generated using GTAS to observe any anomalous behavior. Hourly statistics of tank pressure are used to update mission life analysis as a function of fuel mass.

Trending is frequently provided to external users. Before every Delta-V, Reaction Control System (RCS) pressures and temperatures are provided to FDF in a maneuver planning Excel file. Similarly, after each Delta-V, a maneuver calibration Excel file is sent containing pressure and temperatures during the burns. In addition to the Excel files, an American Standard Code for Informational Interchange (ASCII) file containing 8 Hz data of the Delta-V is sent to both the ACS engineers and FDF. Many NASA AETD engineers, such as Power and ACS, request trending of such mnemonics as battery State-of-Charge (SOC), currents, and voltages and Earth Sensor Assembly (ESA) counts and system momentum.

Although regular data is only kept online for three months, the FOT can still trend any past timeframe by using offline level0 products stored on Compact Disk (CD) - Read-Only Memory (ROM). For any given day, data can be extracted from the CD and a binary file created through high speed subsetting. This binary file can then be made into an ASCII report which can be further analyzed in software applications such as Excel or Kaleidagraph. These ASCII reports have often been transferred to remote users upon request. CD-ROM disks are made and delivered by DDF and contain five days of data on each disk (~73 delivered per year). The statistical data is stored online for the life of the mission and backed up on a regular basis.

One minor problem was experienced with the retrieval of these files from the CD-ROMs in the earlier part of 1998. SDPF was using Hewlett Packard-Unix System (HP-UX) 10.20 to generate the CD-ROMs, while the FOT was using HP-UX 9.5 to retrieve them. Any HP-UX version earlier than 10.20 is incompatible with the International Organization of Standards (ISO) 9660 format. This problem was resolved by first using the GTAS Macintosh (TR2PC1) to extract the files, and then an FTP application was used to send it to the GTAS workstation. This fix has remained in use even though it is a long process of transferring the files.

2.6 External Interfaces and Customer Support

In order to conduct safe and efficient operations and customer support consistently, frequent interaction with other external entities is required. See Figure 2.6-1 below for a high-level flow diagram between the FOT and these various entities. The performance evaluation with each of these interfaces is described in this section, divided between the real-time and offline support interfaces.

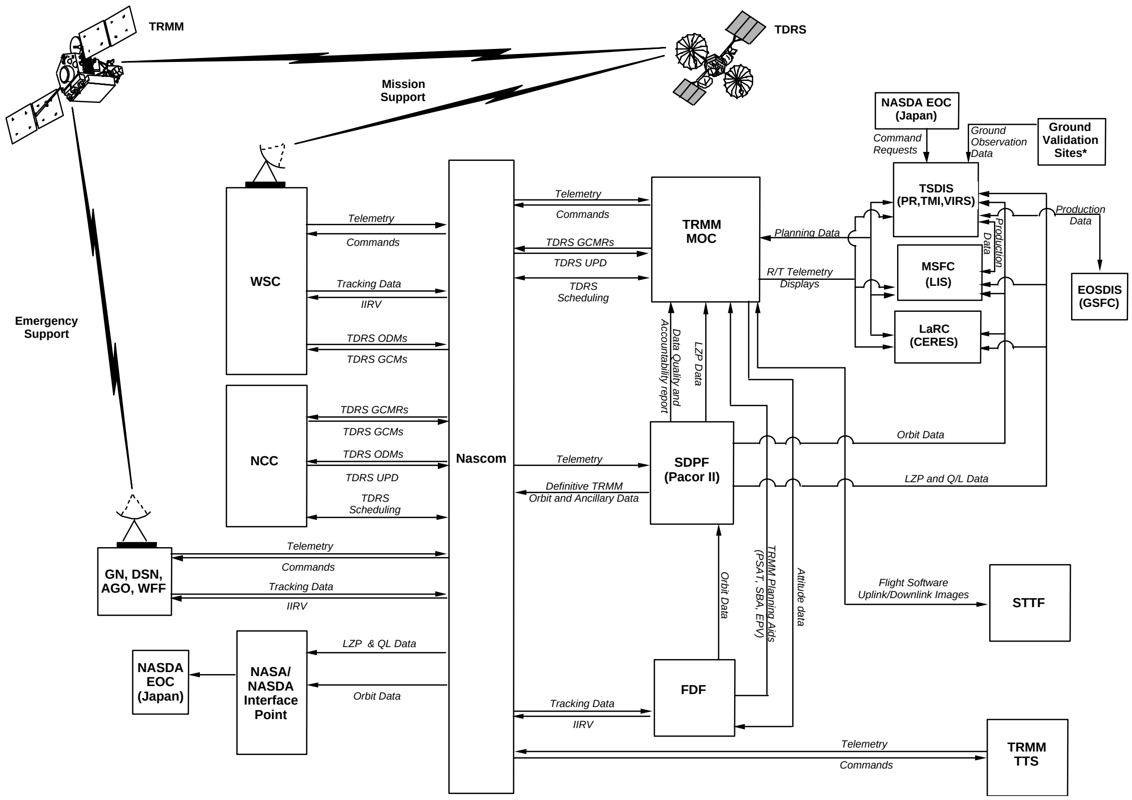


Figure 2.6-1 TRMM External Interface Flow Diagram

2.6.1 Real-time Interfaces

The FOT interacts with each of the entities shown on the left side of Figure 2.7-1, including the NASA Communications Network (Nascom), WSC, the NCC, and occasionally the Ground Network (GN) and Deep Space Network (DSN) sites for emergency support or contingency training and simulations. Nascom support has been frequently utilized to troubleshoot system or network problems by communicating with the Communication (Comm.) Manager and Conversion Device (CD) Manager via SCAMA voice lines. This support has greatly reduced the risk of data loss, especially after the implementation of an entirely new Internet Protocol (IP) configuration in 1998. In addition, the PAs at the NCC and the CSC personnel at WSC have been quite helpful in coordinating activities during anomalous situations or deviations from routine operations. The GN or DSN sites have not been needed since early orbit operations, except for the new IP configuration testing. However, these entities remain a viable option for emergency support or simulation activities. There are plans to perform monthly tests with these sites in 2000 for personnel training and familiarization. The National

Space Development Agency (NASDA) interfaces through Nascom are no longer utilized following the failure of the Communication and Engineering Test Satellite (COMETS) in 1998 and the official cancellation of the TRMM/COMETS experiment which followed.

2.6.2 Offline Interfaces

From an offline perspective, the FOT interacts regularly with each of the entities shown on the right side of Figure 2.7-1, including the SDPF, which consists of the DDF and Pacor II, FDF, FSW, TSDIS, LaRC, and Marshal Space Flight Center (MSFC). Although not shown, the FOT directly communicates with the Earth Observing Center (EOC) using faxed Technical Interface Letters (TILs). Other important support groups, which are not shown in Figure 2.7-1, include the AETD at Goddard Space Flight Center (GSFC), the Sustaining Engineering (SE) group, and the TPOCC Systems Maintenance group (TSMs).

The SDPF interaction consists of Pacor II data processing and DDF product deliveries. Pacor II generates time-ordered 24-hour level0 housekeeping files, which the DDF delivers electronically on a daily basis, as well as weekly on CD-ROMs. These CDs are used to conduct anomaly investigations and long-term analysis beyond the three months of telemetry which is maintained online. In addition to the 24-hour files, mini-level0 data is provided occasionally, on request, for anomaly investigation efforts. Pacor II is notified whenever new events are scheduled, and when certain operations are performed, such as spacecraft clock adjustments. Efforts are coordinated during anomalies or unscheduled events, to ensure all captured science data is processed by Pacor II and to help resolve missing data issues.

Interaction occurs with FDF on a regular basis. Although many of the product transfers are automated and routine (see Appendix F for the MOC/FDF Product Delivery table), the groups often work together to resolve bigger issues and to periodically assess ways to reduce risk. For example, a temporary change to the orbit adjust maneuver strategy was implemented to improve the notification process. Other examples include new updates to ensure correct Yaw maneuver times and ESA interference durations. FDF has provided unique products on request, such as a Leonid storm exposure time report, a PR radiation view report for an inertially fixed orbit test, and special User Antenna View (UAV) files during the Sun Acquisition anomaly in January 1999 (see ACS and Deployables sections). Although nominal FDF support is primarily dedicated to the weekly orbit adjust maneuvers, it also involves work in long-term projects to assist in flight operations such as the de-orbit plan, PR instrument radiation interference, and periodic sensor calibration analysis and recommendations.

FSW has been instrumental in providing the necessary support for closing many of the key issues of the first 18 months. The FSW group develops the simulation test plans and code change reviews, and conducts the subsequent testing and analysis prior to implementing major spacecraft operational changes. These are described in greater detail in the relevant sections. In addition, there is a monthly Configuration Change Board (CCB) to prioritize open software CCRs. FSW also has the responsibility of maintaining the current spacecraft memory and table configuration for the spacecraft and dynamic simulator at the STTF. This table is maintained at the MOC and is the official configuration reference in contingency recoveries, such as spacecraft processor cold starts. Appendix C contains the complete list of TRMM Flight Software CCRs, and Appendix D contains the complete spacecraft Table Load summary.

Command requests are received through TSDIS for the PR, VIRS, and TRMM Microwave Imager (TMI) instruments. These requests are typically forwarded electronically and are followed up by a phone call on the day that daily load is ready. MSFC requests for the Lightning Imaging Sensor (LIS) and LaRC requests for CERES are typically sent directly, either electronically or by phone. To support these operations, listserv e-mail accounts (trmm_mp, trmm_eng, and trmm_fot@listserv.gsfc.nasa.gov) have been developed for mission planning issues, engineering issues, and other general issues. In addition, the FOT receives information requests or Interference Notifications (INs) directly from the NASDA EOC via official TIL or faxes. These interactions have worked quite well and have provided the customers with timely responses. The FOT has also worked with TSDIS on other issues, such as new algorithm update information from ACS data and field campaign coordination.

Another important entity is the AETD. Since TRMM was built and integrated 'in-house' at GSFC, many of the design engineers are still funded to support flight operations activities on an as-needed basis. There have been several major anomalies which required considerable analysis from AETD, including the -Y SA Parking and SA Jitter issues (see Deployables and ACS sections). This support has also been valuable during anomaly recoveries by providing in-depth knowledge of the affected subsystems. The FOT has coordinated many of these support efforts, especially since other parties are usually involved, such as FSW and FDF. AETD also provides support in more routine matters, such as with the Power subsystem. For example, daily power analysis reports and monthly trending reports are generated and archived. This information is then provided to Code 563, which periodically reviews the information and authorizes power maintenance changes. Similarly, ESA and system momentum data is regularly provided to Code 572 to aid in monitoring for potential fogging problems.

The SE and TSM groups have also had a significant presence, especially with the introduction of Y2K compliant system software. The SE group has had the responsibility to build, install, and test new system software releases in the MOC. In addition, the SE group has been quite responsive in troubleshooting configuration problems, and has worked on resolving open Discrepancy Reports (DRs) over the long term. The TSM group has also been responsive in configuring the ground system when new personnel arrive, or when ground system change requests are implemented.

In summary, the working relationship established between all of these groups, many of which were first outlined in the various Operations Agreements (OA) prior to launch, has contributed significantly to the mission success. In the ever-changing environment of a MOC, especially in the context of a new contract such as the Consolidated Space Operations Contract (CSOC) and enormous challenges such as Y2K compliance, the successful and efficient interactions between the FOT and external interfaces has been the key to achieving that success.

2.7 Continuous Risk Management

Risk identification and mitigation is a continuous effort. Many proactive steps are regularly performed to maximize the success of the mission and minimize the potential hazards that are always associated with 24-hour-a-day operations. Several tools developed by AlliedSignal and the FOT are used to maintain the consistent high level of performance. This section discusses the strategy towards risk reduction, as well as some examples of the tools and methods used to implement the risk reduction philosophy. Risk management awareness and training is steadily growing in flight operations. As a result, the tools and practices, already in place, are being adapted to the more formal continuous risk management paradigm of Identify, Analyze, Plan, Track, and Control.

Continuous risk management strategies are being implemented in all aspects of operations, from training to configuration management and control (CM), to spacecraft commanding. One of the primary areas where this is evident is in the certification and training program. Personnel turnover is a reality on any long-term FOT, and the potential loss of valuable knowledge and skills is a relatively high-risk area. To counter this, cross-training is encouraged, and an extensive online database of Local Operating Procedures (LOPs) has been developed. The hands-on approach and one-on-one training, in combination with independent study and online certification, has worked well in developing new employees into well-trained, thorough, and diligent analysts. An advanced training program has been started that includes contingency simulations and a library of critical event playbacks. Reference the Certification and Training section for more detailed information on these topics.

Another area in the operations environment which benefits from continuous risk assessment is configuration management and control. A recent re-evaluation of the MOCR process ultimately resulted in several improvements. The MOCR process is now very thorough and utilizes multiple human verifications in combination with standard format checklists and automated procedure copy scripts, to reduce the risk of human error during any step in the process. It covers any operational change requests, including new or improved procedures, display pages, scripts, programs, or even database and ground system changes. One example of an improvement to the ground system configuration involved the server setup. The MOC once maintained a RAID (Redundant Array of Inexpensive Disks) configuration, but now operates with three separate strings with more reliable hard drives. Daily cron jobs were developed to back up all the data, so that if any one server crashes, the files are still recoverable. Tape backups are also regularly performed for the FSW On-board Computer Support Terminal (OST) computer and the Personal Computer (PC) server.

Many other useful tools have been developed to assist in optimal day-to-day activities. For example, a console binder is regularly updated which contains the escalation procedure flow chart for anomalies, known conditions which can occur, and the appropriate responses, as well as the phone lists and contingency trees necessary for reference when anomalies occur. The LOP database is also frequently updated to retain valuable knowledge and referenced to assist in continuous training and anomaly identification and recovery. Key documents such as console pass plans, shift handover logs, daily summary reports, daily and maneuver load checklists, and weekly reports are generated and used on a regular basis to maintain a consistent level of safety and focus for routine operations and to retain valuable information to prevent repeated problems. Several anomaly detection, identification, and recovery checklists have also been developed as a result of lessons learned from several spacecraft anomalies. The checklists have been found to reduce anomaly identification and recovery time, provide a systematic approach to troubleshooting, minimize human errors in highly stressful situations, and serve as a way to keep the team focused on new developments or changes in operations.

Event tracking is an integral part of any risk management plan. Any deviation from normal operations is recorded as an Event Report, and if the deviation is detrimental, and attributed to FOT actions or decisions, a Root Cause and Correction Analysis (RCCA) report is then written and implemented. This type of database is important because patterns can emerge by simply tracking the problems, minimizing the chances that they will be a significant impact or will be repeated. In addition, the FOT regularly receives operations reports and CCR updates from other missions and keeps track of problems other missions experience in an effort to prevent similar occurrences at TRMM. Monthly Status Review meetings (MSRs) serve as a focal point for any potentially high-risk concerns which could affect the mission from external entities such as FDF, TSDIS, or FSW. All of these efforts have contributed to the success of the mission.

In addition to the tools described above, operations and the spacecraft status are continuously assessed to determine if there are additional proactive steps which can be taken to further reduce operational risk. For example, scripts have been written to generate warnings if events are not long enough for required playbacks, if ESA quadrant blockages are too long, or as a reminder to ensure the daily load was uplinked. There are several CCRs which were opened in an effort to further reduce mission risk, as well. For instance, many of the tables, which were loaded to spacecraft processor Random Access Memory (RAM), will be written to Electronically-Erasable Programmable Read-Only Memory (EEPROM) once they are fully validated. This will reduce recovery time in the wake of a processor cold start, and will reduce the risk of loading an incorrect or outdated table. Similarly, a CCR has been opened which will eliminate all of the on-board TSMs and RTSs which remain from launch. These are no longer relevant, and their removal will reduce the risk of accidentally executing a hazardous launch monitor action. In addition, it was felt that it would be beneficial to have a Data Storage (DS) filter table in place on-board to collect additional attitude data if an anomaly occurs. Currently, this table must be loaded to the spacecraft before changing to the new table.

A work order was generated to implement an automated strategy between the MOC and the STTF simulator. This plan would automatically transfer ephemerides to the STTF each day, and the simulator would be configured to boot up with these ephemerides, unless requested otherwise. This would allow tests to be run, such as Delta-V maneuvers, prior to the actual occurrence with a minimum of setup time required. The Event Report database documents several circumstances which could have resulted in lost science and spacecraft safing reconfigurations, had the various safeguards described in this section not been in place to catch them. Some examples include a Delta-V load that was greater than the on-board 60 second maximum, a Delta-V load that had the wrong time due to Y2K testing, and an ESA interference duration that was greater than the on-board threshold. Continuous re-assessment of potential problems such as these often result in safer ways to conduct the activities. The goal of any effective risk management plan is to continuously determine what the potential risks are, and then develop and implement mitigation plans which either reduce the impact of these risks, reduce the probability that they will occur, or increase the timeframe until the occurrence. The FOT has adopted this paradigm as a guide, and the success of the mission to date is a direct result of the tools and practices described in this section.

2.8 Upcoming Events

There are several upcoming events which will challenge the operations team in the next several months. Two of the primary activities include the 1999 Leonid Storm in November and the Y2K rollover. Other activities highlighted in this section will be discussed in greater detail in the appropriate subsystem or instrument sections.

The Operations Plan for Leonids activities this year will be based on the 1998 timeline, with a few modifications based on the lessons learned. One of the primary differences will be the instrument shutdown timing. In 1998, the instruments were all powered off within the same orbit during eclipse. The unforeseen outcome of this was a spike in the Battery-2 Cell 1 voltage during the following charge cycle, due to the sudden reduction in load to the batteries. This battery cell has experienced higher voltage levels than the other battery cells, and power maintenance operations are therefore constrained by the possible effects on this cell. As a result, instrument shutdowns this year will be spread over three orbits and grouped according to power draw. The shutdowns will also be performed during orbit day to further minimize the effects on the Battery-2 Cell 1 voltage peak. Another change will be the use of an official storm Internet website to determine when it is safe to authorize the return to normal spacecraft operating conditions. An automated notification e-mail system has also been put in place, and was successfully tested during the Perseid meteor shower of 1999. In 1998, there was considerable uncertainty and ambiguity across the missions as to when the Leonid Storm was officially over and when it was safe to resume normal operating conditions. For 1999, the official site will be used to confirm that the storm is past, and MD authorization will be required as the final approval to resume normal operations.

For Y2K, the MOC ground system and PCs are validated as rollover and leap year compliant (see Ground System section), and the timeline of operations activities is being finalized. This timeline covers all flight operations activities from Thursday, December 30th through Tuesday, January 4th. Special access badges, effective Close-of-Business (COB) December 30th, will be issued to FOT, FSW, SE, and AETD personnel, in the event that additional support is required. There will be Systems Engineer support during the Friday through Tuesday period in case there are power-related problems in addition to the potential software and hardware problems related to the year change. FDF has stated that they will be providing support during this timeframe as well.

As an added precaution, a Delta-V maneuver will be performed on December 29th which will boost the spacecraft above the nominal science orbit 'box' to allow maximum time before the next maneuver. In addition, all daily loads and required FDF products for the six day timespan will be delivered in advance in case there are communication problems. Finally, if problems occur with the SN, and communications cannot be established with the spacecraft before the end of the day, the daily loads will incorporate a spacecraft safing sequence which will autonomously place the spacecraft in a Sun Acquisition mode. Under such a scenario, DSN or GN events could also be scheduled to monitor spacecraft health and safety until the SN is operational again.

There are several additional high-priority activities scheduled for upcoming months, many of which are documented in the CCR database (see Appendix D). For instance, FSW is currently developing the test plan for a new ACS flight code patch. This patch is expected to eliminate the SA vibrations which occur at high Beta angles, due to the feedback loop between the attitude control gyros and the SAs (see ACS section). Also, the CERES instrument will likely return to full-time operations following a successful launch of the Terra spacecraft, and this could entail several changes to operations. For example, there is a pending request to change the CERES instrument status during autonomous Sun Acquisition or Safehold load-shed transitions from a powered-off state to a standby state (see CERES section). Another high priority issue includes finalizing the 'No Clock' scenario, in which operations could be performed without the use of a viable Frequency Standard (FS). There is also a new Power System Interface Box (PSIB) patch being developed to fix a code subroutine which could potentially affect some important PSIB functions (see Power section). These are just some examples of the many upcoming events scheduled for the months ahead.

3. Ground System

This section is the general overview of all MOC hardware and software operations, including the IP network, GTAS, and Y2K validation.

3.1 MOC Hardware

The only major hardware problem for the MOC was the prime file server issue, which arose before Launch. This caused a re-evaluation of the system layout and resulted in the redesign of the overall string configuration.

The RAID used as the prime file server, for both real-time and mission planning operations, proved to be very inefficient (after unsuccessful attempts with two different units). Large amounts of downtime were experienced due to the constantly failing platters of the RAID, with the concentration on one disk in particular, which required frequent rebuilds to recover (Event #17). Almost all components were replaced in various attempts to eliminate the failures, including the controller (98-015) and chassis (98-064), but nothing was successful. Intermittent hangs (Event #7) and crashes of the server workstation (WS) (TR3WS1), due to the interface, also hampered operations repeatedly. The workstation and interface card were replaced (98-047), but the new equipment did not eliminate the problems. This led to a re-evaluation of the MOC configuration and the decision to replace the RAID with hard drives; especially when the memory card failed on 98-065 (the cause was speculated as a metal shaving short from the new chassis - Event #19).

The replacement of the RAID allowed the MOC to be redesigned to a three-server configuration: a prime real-time string; a prime mission planning and simulator string; and a string for redundancy of both systems, as well as the prime for trending. This allows much more flexibility in testing and anomaly investigation, since toggling systems between real-time coverage and simulation tended to be timely and error prone. The dual-disk hardware design originally implemented, one for system software and one for operations data, was modified to use one 9 GB disk for the two together (eliminating links). Once the software was implemented, existing cronjobs were modified to perform system maintenance, provide reliable on-line backups, and archive data with little interference; which allowed the three-server configuration to go active on 98-131. No problems have been experienced that are attributed to this new scenario.

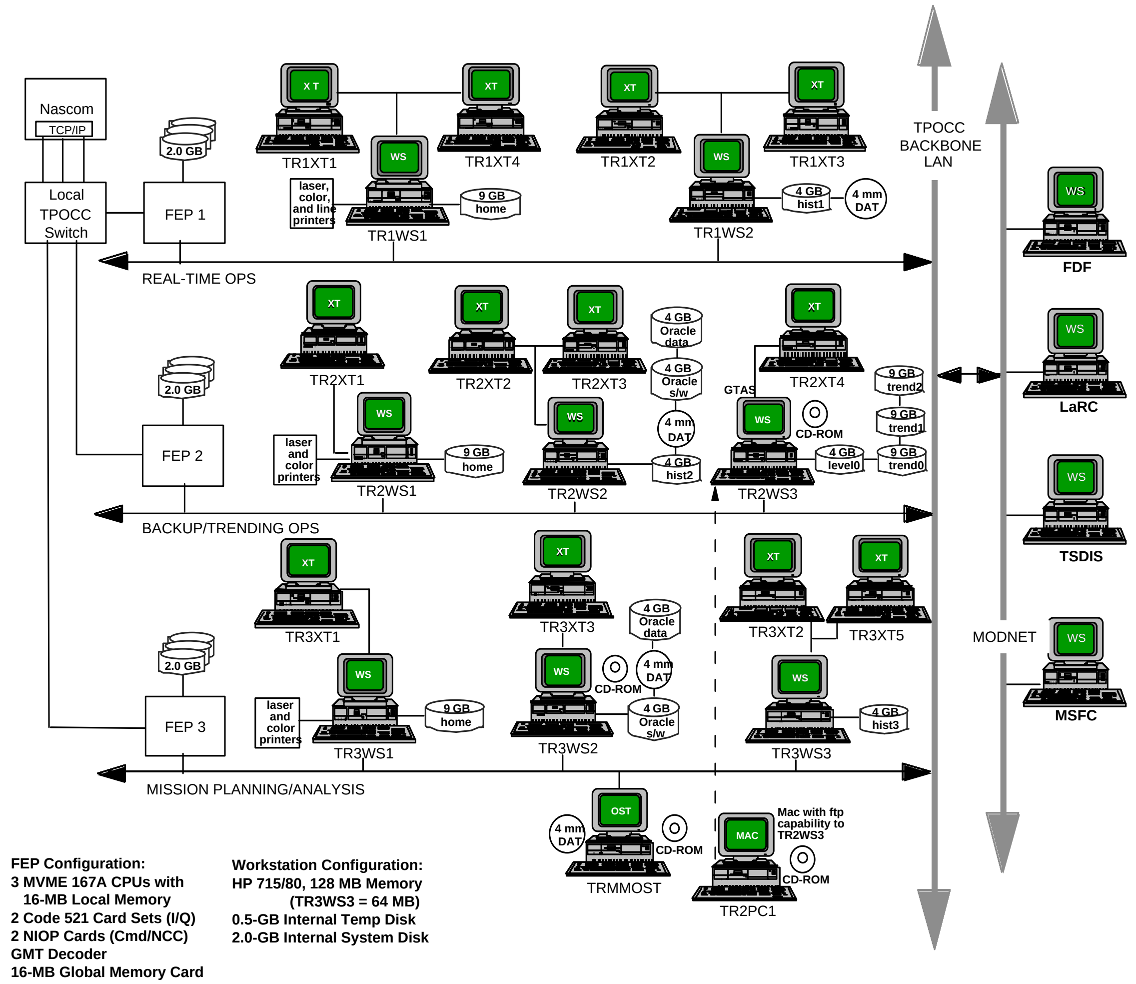


Figure 3.1-1 TRMM MOC Diagram

Many problems have been experienced with the Desktop Key Set (DKS) phone system (black phones). There are continual phone and line failures for extended periods of time. Phones will occasionally ring for no apparent reason, there is major interference between incoming calls and active ones, and individual interfaces fail, which make the phone unusable. The usual resetting is not always successful in eliminating problems, and sometimes most of the units are down at once. There have been several occurrences when the MOC was not able to receive any calls for an extended period of time. The system has been advantageous overall for monitoring operations, allowing access to the numerous voice loops from anywhere in the MOC.

The building Mission Operations and Data Directorate Operational/Development Network (MODNET) rack, that was located in the Mission Analysis Room (MAR), was moved to the basement to make room for the TCP/IP Programmable Telemetry Processor (PTP) rack. This allows easier accessibility for maintenance and outside Local Area Network (LAN) investigation without interfering with operations.

The FEPs have had numerous hardware replacements thus far. Cooling fans have failed several times amongst the three FEPs, causing temperatures to rise towards the failure threshold of 85 °F. Several cards have required replacement, such as the FEP-1 Reed-Solomon (RS) and Data Capture (DC) cards and the FEP-2 b and c processor cards. The power supply of FEP-1 also failed and needed to be replaced. The biggest problem experienced with the FEPs is in the handling of bad quality data. If there is a broken signal (front end repeatedly locks and unlocks), the internal buffers become overflowed, and the front end can no longer process data; requiring a reboot to clear. Since these times can be crucial, the crashes can be a severe impact to operations. Though still experiencing these, and other, occasional crashes, the FEPs have proven much more reliable now than they were during the pre-launch period, exhibiting the ability to remain online for over 24 hours without requiring a reboot (nominally rebooted at the end of every 12-hour shift).

General hardware failures have happened regularly. Several Block Error Detectors (BEDs) have exhibited failed connections to the backplane, such as the NCC interface Port #3 (Event #8), or complete failures, such as BED-2. The root drives on the backup Oracle and GTAS servers have failed as well as numerous tape drives and disk drives, such as the app-disk for the prime Oracle server and a 4 GB trending drive for GTAS.

3.1.1 Internet Protocol Network

Testing officially began with the Internet Protocol (IP) network on April 16, 1998 (98-106). During the following six month period, the FOT tested with White Sands Ground Terminal (WSGT), Second TDRS Ground Terminal (STGT), NCC, GN sites such as Wallops (WPS) and Santiago (AGO), and DSN sites such as the DSN Testing Facility (DTF-21), Goldstone (DSS-16), and Canberra (DSS-46): a total of approximately 25 hours of testing, excluding the SN Customer 48 Hour Operational Readiness Test.

All NCC tests involved receiving User Performance Data (UPDs) and transmitting Ground Configuration Message Requests (GCMR), such as coherency switches. The MOC was officially transitioned to NCC IP on 98-280.

The tests with WSC were also very extensive and included commanding, recorder playbacks, and table dumps. Data rates consisted of 1/1, 1/4, and 32/2048 kbps. Intermittent bursts of Cyclic Redundancy Check (CRC) errors were encountered on the Q-channel at the high data rate, but it was resolved early in the testing by modifying the way that data came across the network (pulse not stream). The SN lines were transitioned to IP on 98-280, after a successful participation in the SN Customer 48 Hour Operational Readiness Test.

The GN and DSN tests included data rates of 1 and 1024 kbps composite (32 real-time strip&ship and post-event playback downlink). Tests used both a tape and the spacecraft as the data source. Commanding was successfully performed with all sites by verifying receipt of command echo blocks. The GN/DSN legacy line was switched over to IP on 98-306.

TRMM has three PTPs in a rack located in the MAR: two for prime operations and one for a backup. Currently, there are three channels configured to the Cornet Switch on each PTP, leaving one channel available on both PTP 1 and 3 (PTP 2 only has 3 channels). For a detailed diagram of the network, see Figure 3.1-2. The current PTP software is Version 4.0.5.3. This version may require manual Y2K rollover by the CD Manager, but since events are restricted from crossing the year change, no interference to operations is expected.

The only problem experienced is occasional hangs that occur with the PTPs. The CD Manager must grant permission to perform manual resets to recover, and operations are impacted for a few minutes until the software is re-initialized.

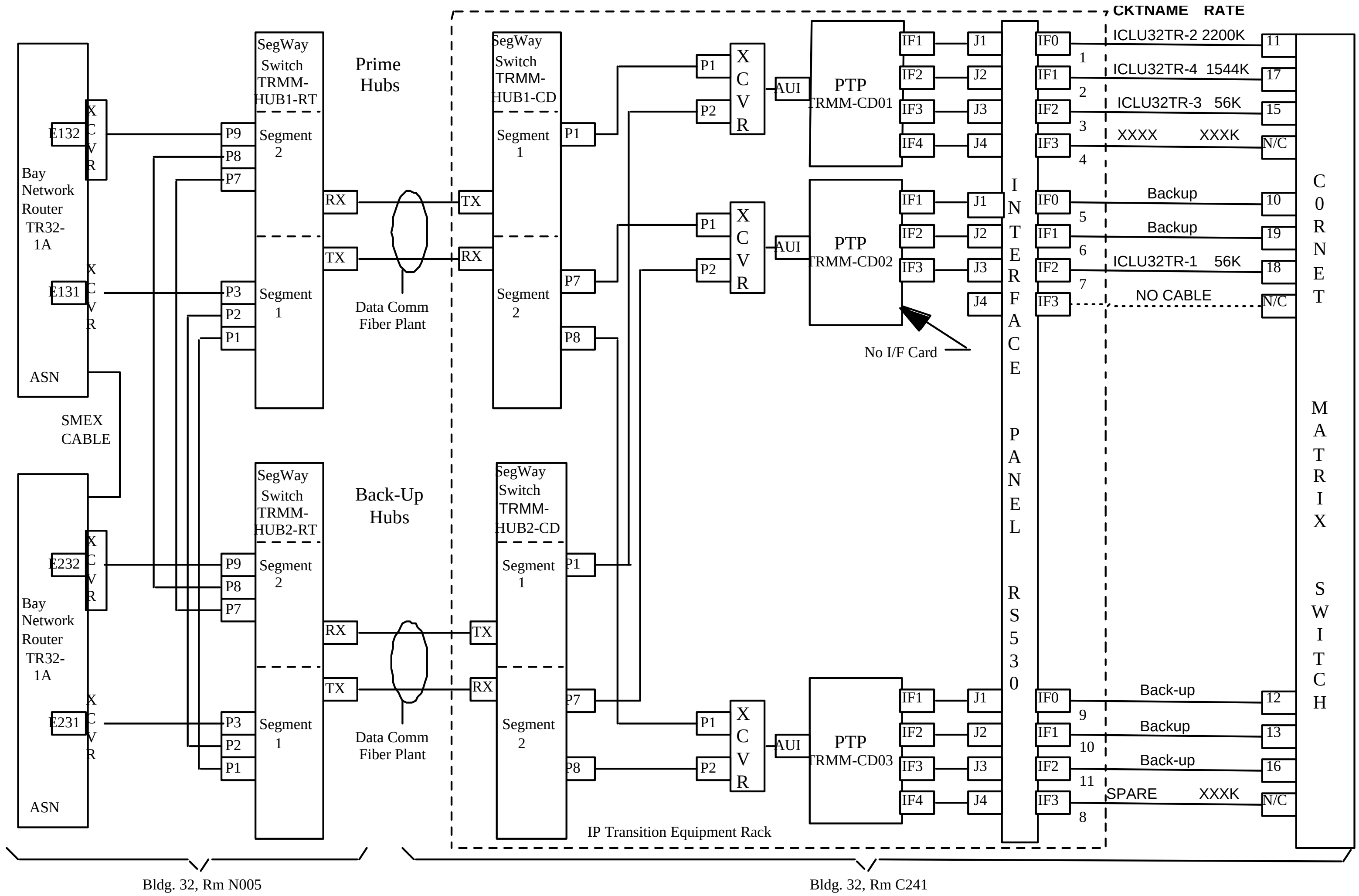


Figure 3.1-2 TRMM IP Diagram

3.2 MOC Software

The MOC has received two major system software releases since Launch: 7.0 and 8.0. Release 7.0 was designed to fix most of the major Launch & In-orbit Checkout (L&IOC) problems, including Return Data Delay (RDD) clock correlation and the ATS Jump command. Release 8.0 was the Y2K upgrade, which also entailed a few small fixes discovered during the modification.

The real-time portion of Release 7.0 was delivered to the backup string on 98-084, to allow parallel testing with the prime operations string. A failover script was developed to easily switch back to the previous release (6.4) in case of major difficulties. After testing was completed, the prime system (strings 1 and 3) was upgraded in April 1998. The mission planning software was delivered on 98-117.

To prepare for the three-server reconfiguration, Release 7.0 was updated with modifications to scripts needed to make a three-string system work. In May 1998, Release 7.1 (mission planning and real-time) was delivered to all three servers. In July 1998, the MOC received the GSOC upgrade 98.01 to exclude the earth occultation (to match the on-board scenario) and modified the Earth Sensor template to better model interference regions. FORMATS Release 8.4.2 was installed in August 1998.

A major impact in software testing has been the loss of the SOTA in Building 14. The SOTA bays were used as an intermittent step for software deliveries and DR investigation, eliminating some of the interference with operations. It allowed configuration problems to be isolated from software problems much more easily. Now software discrepancies must be investigated in the MOC, and software changes are delivered from development directly to the redundant system.

Software crashes still occur on occasion, forcing failovers for entire or partial events. These are usually due to state manager problems, and equipment reboots continue to be sufficient to eliminate them.

TRMM FEPs experience the same year-end rollover problems as other missions (Event #80), which require manual intervention to fix. This is not a major operational impact and is cleared with the usual work-around of setting the year.

3.3 Generic Trending Analysis System

The Generic Trending and Analysis System (GTAS) has undergone some major changes to improve the reliability of the system. Currently, GTAS is used on a daily basis for providing necessary trending of spacecraft telemetry.

The original hardware configuration of the GTAS workstation (TR2WS3) included one 4 GB hard drive (level0) and a juke box capable of holding 32 optical disks (four months of data). Each disk was formatted to include approximately four days of trending and was recycled when it became the oldest disk in the system. This was a time-consuming process because each disk took over 90 minutes to format.

In March of 1999, during a software upgrade, a drive failed in the juke box making it inoperable. Due to the lack of technical support under the new CSOC contract, and the cost to replace the drive, the FOT decided that the juke box (removed from MOC on 99-169) should be replaced with hard drives. The GTAS hardware was then changed to include one 4 GB hard drive (level0), three 9 GB hard drives (Trend, Trend1, and Trend2), and a tape drive. All data is now ingested daily on the 9 GB hard drives, which are capable of holding three months of data. A partition format, which holds the same amount of data as an optical disk, now takes only 5 minutes, instead of 90. All statistical data partitions are autonomously backed-up by a cronjob as a safeguard against disk drive failures.

The GTAS software has been upgraded twice. The first, Release 5.2.1, was delivered and installed in March 1998. Highlights of this release included a Partition Formatter and a Partition Manager Tool. The current release, 6.0.1, was installed in February 1999. The main purpose of this release was to make GTAS Y2K compliant and HP-UX 10.20 compatible, although it did include upgrades such as a Report Writer Append function. No new versions will be delivered unless a major DR is written against the system.

3.4 Operation Database

There have been two operational database (ODB) builds since Launch. Each new database was first made operational on the backup string until proper verification could be made. Once all the contents were confirmed (2-3 weeks), the new database was then moved to the prime system (strings 1 and 3). All steps from initial build to final verification are written in a detailed LOP.

On 98-026, ODB 9.1 was compiled to include limits changes since launch, new derived mnemonics (ground based equations based off system variables or telemetry), and command criticality changes. ODB 10.1, created on 98-310, contained additional limits changes (incorporated temporarily through a procedure up to that point) and new derived mnemonics.

3.5 Year 2000 Preparation

The Year 2000 (Y2K) upgrade (Release 8.0) began with the prime real-time server (string 1) on 98-257. This string was upgraded first because it caused the least impact to operations. This upgrade included the Operating System HP-UX 10.20, an Oracle upgrade to Version 7.3.5.1, MOPSS Timebox 10.1, and several local changes. String 1 was returned to operations on 98-356, and the backup server (string 2) upgrade was begun on 99-011. That string was returned to operations, and the prime mission planning string (string 3) was started the week of 99-081, moving the mission planning operations to the redundant string. This last string has not yet been completed but is expected to be placed back in operations later in 1999, thereby concluding certification of the MOC as Y2K compliant.

Two hardware upgrades were required for the Y2K modifications. The root disks for all terminals were upgraded from 1 MB to 2 MB, and the RAM was upgraded for all terminals (except for TR3WS3): Workstations now have 128 MB and Xterms (XT) have 14 MB. The Oracle disks were upgraded to 4 GB (after a couple of disk failures), and GTAS was modified to use three 9 GB drives, instead of the original juke box (see GTAS section).

4. Observatory Subsystem Operations

This section describes the various subsystem activities and performance of the Observatory during the timespan of January 1998 to June 1999. Because many activities are involved in multiple subsystems, the relevant information will be presented in each subsystem individually. A figure of the spacecraft with some pertinent subsystem components is presented below.

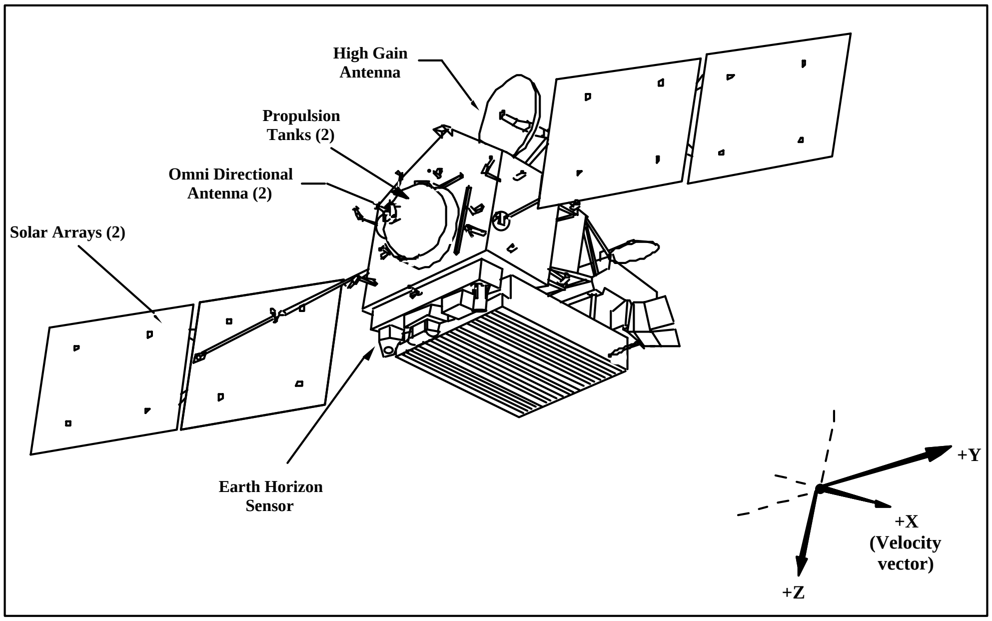


Figure 4-1 TRMM Spacecraft

4.1 Attitude Control Subsystem

The Attitude Control Subsystem (ACS) has performed as expected. Operations were highlighted by two autonomous transitions to Sun Acquisition mode, due to tight Failure Detection and Correction (FDC) limits. The heating of the -Y solar array drive has been a major concern and has even warranted an ACS software change. There has also been a SA Jitter anomaly, which resulted in a redistribution of the Magnetic Torquer Bar (MTB) control (100% on MTB B). The ESA has shown preliminary signs of fogging in quadrant one, but trending of the detector counts show that no action is required. There have also been many system table (see Appendix E) and FDC test changes (see Appendix F).

4.1.1 -Y Solar Array Drive

In the last year, the feasibility of parking the -Y solar array was studied, due to a high temperature experienced with the solar array drive (see Deployables section). Investigation of the ACS was done by Code 571 and 572 engineers to include parked and frozen array configurations. After analyzing various angles, Power and ACS engineers decided +30° would be the best angle to park the -Y array. The +Y array would track between ±130° during daylight and feather at +30° in eclipse.

The easiest way to park the array, without involving major FSW patches, was to use the GSACE sequence halt command. For the parked array configuration, it was determined that both arrays must go to the index position for Sun Acquisition and Safehold modes for ACS and power reasons. The Safehold case requires no action because there is a hard-line between the Attitude Control Electronics (ACE) and the GSACE where the halt command is overridden. However, Sun Acquisition would require a GSACE sequence enable command before the -Y solar array could go to index. The best way to do this would have been to modify RTS #5 (SUNACQ) to include the enable command. This RTS is always executed when the spacecraft transitions to Sun Acquisition mode, due to the tripping of TSM #16 (ACS Sun Acquisition Mode Monitor).

For any -Y solar array non-rotating configuration, ACS Table #55 and 66 would have to be modified prior to returning to Normal mode. The MTB software limit in Table #55 would be changed from 225 to 325 Am^2, and the magnetic unloading gain in Table #66 would be changed from 2.0 to 0.5 $Am^2/Nms\text{-}\mu T$. The parked array scenario would also include disabling FDC test #113 (-Y solar array commanded versus sensed position check). The frozen scenario would include modifying the magnetic unloading gain from 2.0 to 0.5 $Am^2/Nms\text{-}\mu T$ in the ACE Control Parameters Table via a command. This would have to be done for both ACE A and B and would have to be uplinked again in the event of an ACE warm or cold start. Upon transition back to normal mode following a failed array drive, ACS Table #76 (Solar Array Parameter Table) would have to be changed to feather the +Y solar array in eclipse at the same position as the failed -Y array.

Various simulations for a non-rotating array were done, by Code 572, and included both directions of flight (+X and -X), a failed reaction wheel, and Yaw maneuvers. The tests concluded that successful momentum unloading could be done. If system momentum kept building and the MTBs became saturated, one-shot thruster pulses could be used. The Reaction Wheel Assembly (RWA) manufacturers, Ithaco, confirmed that the frequent zero-RPM crossings, due to a ‘fixed’ array, would not harm the wheels. The reaction wheel activity was found to increase, which meant a higher power requirement.

One other concern with the non-rotating array scenario was whether the increased exposure to the sun of the Diode boards, located on the back of the array, would cause them to be more prone to failure. Thermal analysis concluded that this would not be a concern.

Instead of parking the -Y solar array, the Solar Array Parking Readiness Review board decided to remain in the current configuration because of power concerns (see the

Deployables section). There remain many decisions for a possible array drive failure. First, ACS tables #54 and 66 could be loaded in Normal mode, before the array drive fails, to help relieve the criticality of communicating with the Observatory immediately following a failed array drive. Simulations must be performed to determine if this table change is needed in Sun Acquisition mode. The ACE gain change must also be tested by FSW. The FOT has fully tested the one-shot pulse-firing procedure and have readily available the spreadsheet developed by Code 571 of which thruster to fire if high system momentum becomes a problem. The PR survival heater relays could be opened to conserve power in an ACS safe mode (see the PR section). ACS engineers are also looking into the possibility of pitching the spacecraft to warm PR to limit the cycling of the heaters. The FOT has developed a checklist that will help Console Analysts quickly identify a failed array drive and what actions must be taken.

4.1.2 Operations

TRMM launched with the ACS flight software containing the coefficients for the 1995 epoch magnetic field model, but an epoch of 1990 was erroneously hardcoded into the software. It was unknown at the time of the magnetic field model update in the Spring of 1997 that the epoch of the model was hardcoded. FSW was tasked with building RAM and EEPROM software patches to correct the coefficients (CCR #005). On 98-253, at 20:25, the Magfield patch was loaded to ACS RAM. FSW is currently waiting for the Code 572 ACS engineers to verify the simulation results of the RAM patch before updating EEPROM, since these coefficients are only used in Contingency mode.

As part of In-Orbit Checkout, ACS System tables #55 (Gyro Parameters Table) and 56 (Gyro-To-Body Transformation Matrix) were uplinked on 98-061 with calibrated values for the primary Inertial Reference Unit (IRU). Table #55 was later revised and uplinked again on 98-104 with the redundant IRU calibrated data. In addition, seven backup IRU tables (#56) were created for uplink in the event of a gyro failure.

On 98-190, ACS System tables #57 (Three-Axis Magnetometer (TAM) Parameters Table), 58 (TAM to Body Transformation Matrix), and 67 (MTB Contamination Table) were uplinked to the spacecraft. These were the final calibrated ACS tables from FDF for In-orbit Checkout.

There has been one Digital Sun Sensor (DSS) calibration since January 1998. To improve Yaw update sizes, ACS system tables #64 (DSS Parameter Table) and 65 (DSS alignments) were modified and uplinked on 99-056. By loading these tables, Anomaly #25 was closed.

At the beginning of 1999 however, it was noticed that the yaw updates were getting larger again (see Figure 4.1-1). Recent trending has shown that the size is influenced by the seasons and direction of flight (larger in +X direction). During the time Yaw updates were large, the pointing accuracy violated the 1-σ pre-launch constraint. Analysis showed that further DSS calibrations would have minimal effects, because irregular behavior of the ESA Offset Radiation Source (ORS) may be the significant contributor.

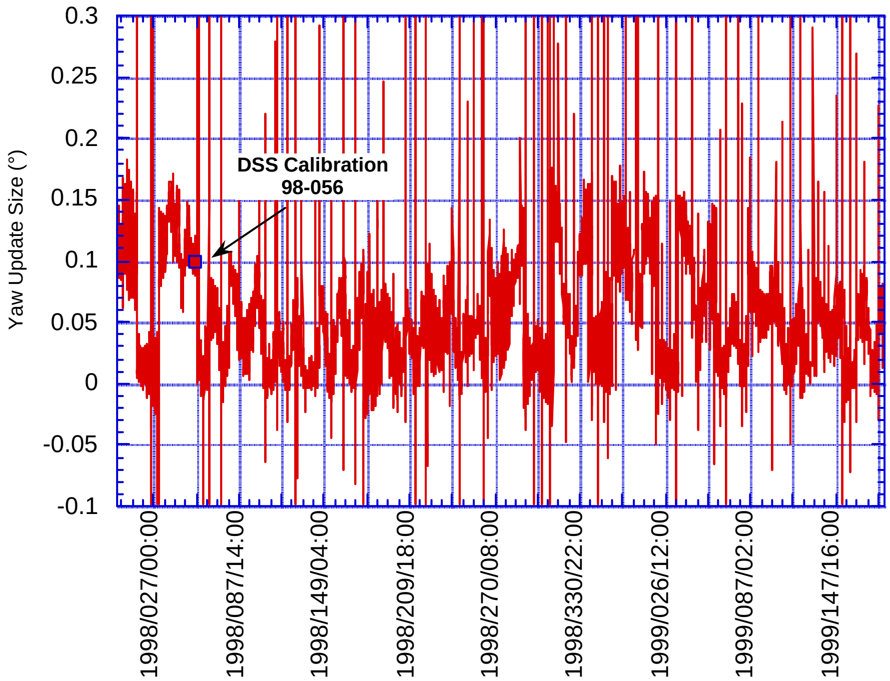


Figure 4.1-1 Maximum Yaw Updates

A Contingency mode version of the DSS table (#64) has been created and tested by FSW for uplink if needed.

Originally, ACS System table #85 (Ephemeris Limits Table) had a tolerance of 400 km and 0.03 km/s between the propagating and new TDRS EPVs. Due to the timing of TDRS maneuvers and the frequency of the EPV updates, the vectors often fail the continuity constraint checking for position and velocity (Anomaly #60). The FOT was temporarily fixing this by uplinking a different version of Table #85 with position limits of 2400 km and velocity limits of 0.18 km/s. Once the EPVs are confirmed as propagating, the original table is copied from EEPROM back to RAM. CCR #035 was opened for FSW to create a permanent table with more reasonable values. On 99-060, a new Table #85 was created and uplinked with a new position continuity limit of 800 km. On the first TDRS EPV update with the new table, some vectors still failed the velocity check. Through investigation, it was found that the velocity needed to correspond to the position limit. After a month of trending, a new table is currently being generated and tested with values of 850 km and 0.062 km/s.

On 98-316, ACS System tables #51, 53, 55, 56, 57, 58, 59, 61, 64, 65, 67, 73, 81, 82, and 83 were copied from RAM to EEPROM to reduce the number of tables that need to be loaded following an ACS processor cold start. These are tables that have been changed since Launch. All tables were then dumped from EEPROM for verification.

On 98-326, the TRMM daily EPV failed the 50 km continuity limit threshold (Event #68). Investigation showed that the vector was 3 km over the 50 km X-axis position threshold. FDF regenerated and re-delivered a new vector file with no changes to the vectors. A decision was made to load a version of ACS System Table #85 which changed the 50 km continuity limit to 300 km. After the EPV was verified as propagating, the original table was copied from EEPROM. The same failure occurred on 99-050, but this time the Y-axis position failed by 3 km over the 50 km position threshold (Event #86). The same action was taken to get the EPV to pass continuity. Both times this event occurred the day after a Delta-V maneuver. Investigation of this anomaly is ongoing.

ACS System Table #84 (Ephemeris Model Coefficient Table) defines the spacecraft mass, which is used for ephemeris propagation. This value changes after every Delta-V maneuver and should be updated approximately once per year to ensure efficient ephemeris propagation. CCR #037 was opened to update this table with a more recent mass value. On 99-124, a new Table #84 was uplinked with a spacecraft mass value of 3368 kg (4.4% change in original mass). Moment of Inertia (MOI) is also affected by amount of fuel used and may be changed (table #54). MOI is used to calculate magnetic torquer bar currents for momentum management. A work request has been opened for FDF to determine if the MOI change is large enough to require a table change.

4.1.3 Earth Sensor Assembly

In order to alleviate the large position error spike observed during the transition from two or three to four head sensor control of the ESA (Anomaly #45), a revised ACS system table #83 (First Order Filter Coefficients) was uplinked on 98-037, to disable S-detector filtering. The ESA radiance filter was left unchanged. With the filter off, there is a slightly greater noise level in the position error data, but not enough to influence operations. The large spike that caused the anomaly is greatly reduced, thereby minimizing the possibility of repeating the FDC failure. Trending shows no degradation of ACS performance due to the absence of S-detector filtering.

The ESA has exhibited anomalous fogging behavior over the past 9 months. The S-counts in quadrant 1 have drifted above the expected plateau observed since Launch. It appears that this behavior began around the time of the Deep Space Calibration in September of 1998 and has steadied at approximately 1300 counts (600 originally - see Figure 4.1-2). Since this is well below the concern threshold of 2500 counts, and no other quadrant has displayed such a distinct trend in any counts, the manufacturer is not concerned with the performance of the sensor. If the drift becomes too great, or begins to cause problems in attitude control, then a bias will be loaded to reduce the overall effect.

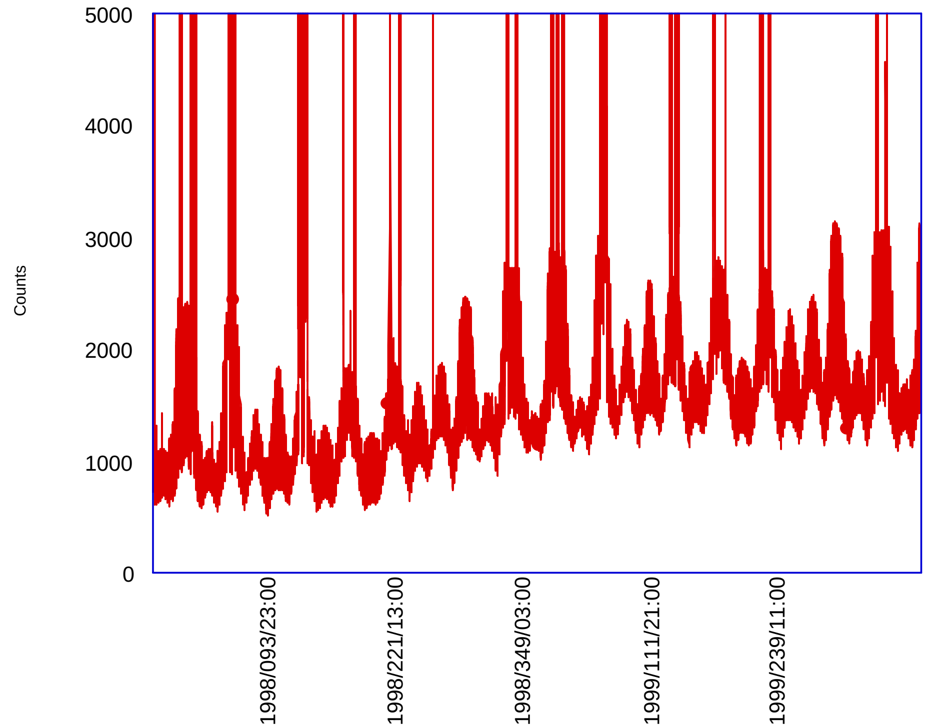


Figure 4.1-2 S-Counts for ESA Quadrant 1

4.1.4 Solar Array Jitter Anomaly

An undetermined oscillation has been observed with the solar arrays and body momentum which begins shortly before orbit noon. This oscillation appears at Beta angles above 55° (absolute) and increases as Beta magnitudes increase. The phenomenon became apparent on 99-164 when the difference between the MTB commanded and sensed dipole moments in the X-axis (FDC #9 and #12) exceeded 40 Am^2 for over the 20 second threshold (Anomaly #74), causing a reconfiguration from the normal 50% control distribution over each coil to 100% on MTB B (FDC Action #23). The large difference was due to a “banging” of the current through the coils, because of the irregular commanding from one extreme to the other (positive to negative and vice versa), to compensate for the oscillation. Since this banging was not allowing the bars to control the behavior, the momentum gradually built up in the system, though not to any dangerous levels. The possibility of a MTB hardware failure was quickly eliminated since both coils exhibited the same behavior and were performing as commanded. Both TAMs were also operating nominally. The frequency of the oscillation was calculated as ~0.75 Hz, which was determined as the first harmonic of the arrays during pre-launch. It is difficult to conclude at this time whether the SAs are the source and why (see Figure 4.1-3), but it is increasing slightly over time. The FDC threshold for the duration has been modified from 20 seconds to 5 minutes to keep this behavior from affecting the nominal configuration, but still allow the detection of a complete failure of one of the coils.

A patch is being developed to eliminate the feedback loop between the arrays and spacecraft momentum and to track the arrays for a nominal attitude. Eliminating the feedback loop within the control algorithm will prevent the magnitude of the oscillation from being continually magnified. Tracking the arrays using a nominal attitude will prevent any momentum reactions from causing the arrays to be spuriously commanded. This would stop the array oscillations from directly impacting the overall spacecraft control.

4.1.5 Sun Acquisition Mode Occurrences

The ACS has autonomously transitioned to Sun Acquisition mode by FDC tests on two separate occasions. Both anomalies were due to tight pre-launch limits and not system failures.

The ESA experiences periods of lunar and solar interference, with the stronger solar interference occurring when the solar Beta angle is between ±33° and 55°. On 98-115, FDC test #83 (ESA Quad 3 Blocked) failed, sending the spacecraft to Sun Acquisition mode (Anomaly #67 and Event #31). Analysis revealed that the cause of the anomaly was an underestimated value of 10 minutes (1200 counts) for the maximum ESA interference duration in ACS System table #53 (FDC Statistics Table). Later confirmation by FDF showed that periodically (3 or 4 times a year) the Sun is immediately followed by the Moon across the widest part of the ESA quadrants, resulting in continuous interference durations greater than 10 minutes.

FSW generated a new Table #53 with a value of 13.3 minutes (1600 counts) that was uplinked on 98-190. On 99-047, it was discovered that the blocked ESA quadrant would exceed the new limit of 13.3 minutes. FDC tests #81-84 were disabled before the corresponding action executed. New analysis by FDF showed that the blockage limit was actually closer to 14.5 minutes because the Sun/Moon path across the quadrant is really

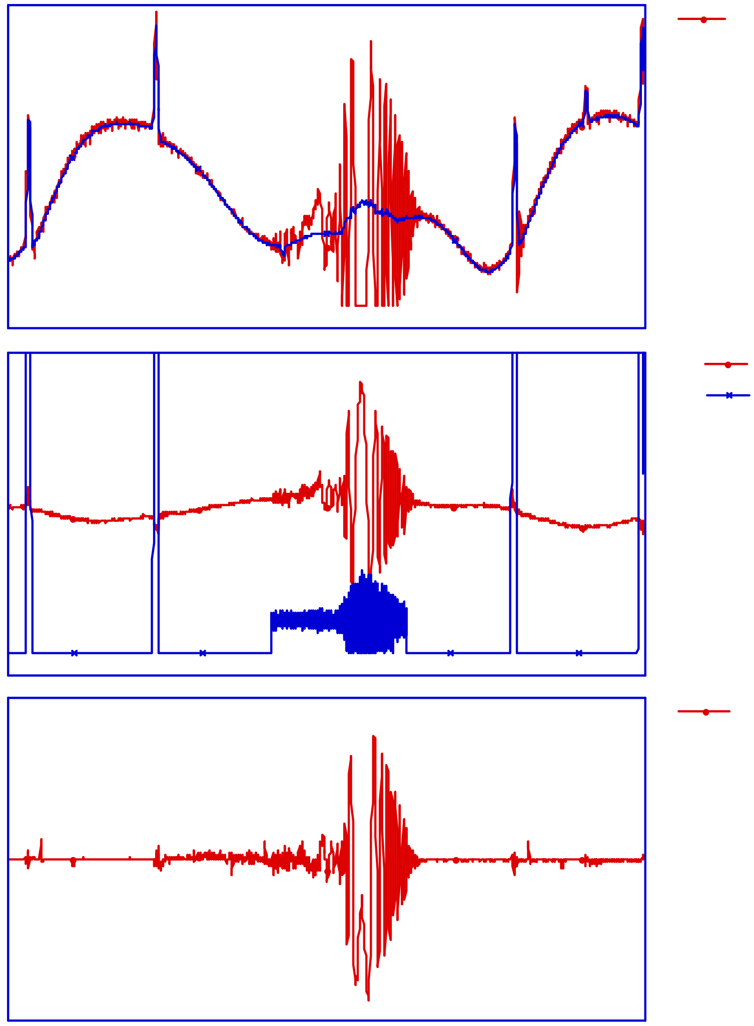


Figure 4.1-3 MTB Anomaly

an arc, not a straight line. A new table with a limit of 16 minutes (1920 counts) was uplinked on 99-097. FDC tests #81-84 were re-enabled on 99-102.

The second Sun Acquisition occurrence happened on 99-003 as the result of FDC tests #112 (+Y solar array position check) and #113 (-Y solar array position check) tripping following a Delta-V maneuver. A detailed explanation of this anomaly can be found in the Deployables section.

4.1.6 Yaw Maneuver Performance

Yaw maneuvers of 180° are routinely performed to keep the +Y side of the Observatory out of the Sun, due to VIRS and battery thermal constraints. The mission planning scheduling criteria uses the first eclipse time after passing the ±1° Beta angle. A total of twenty-three 180° Yaw maneuvers were performed during the span of this report and are summarized in Appendix F. There have been no 90° maneuvers during this time. Trending, which is generated after every maneuver, shows that the ACS is performing as expected, and typically takes about 16 minutes to perform the 180° turn and return to Normal mode.

4.1.7 Delta-V Performance

For information on actual thruster, tank, and line performances, as well as a table summary of the Delta-V maneuvers, see the RCS section. All of the Delta-V maneuvers generate a pitch disturbance torque due to slight thruster misalignments. As a result, the Instrument Support Platform (ISP) -Pitch and Lower Bus Structure (LBS) +Pitch thrusters typically off-modulate to maintain axis stability. Similarly, when the spacecraft is +X forward and the Lower Bus Structure (LBS) thruster set is used, a -Yaw disturbance torques occurs, and the -Yaw thruster off-modulates to compensate.

4.1.8 Deep Space Calibration Performance

Due to interference seen in TMI data (see the TMI section), an Inertial Hold Deep Space Calibration maneuver was planned on 98-245 for 11:33:41 to 13:05:08 (orbit noon to orbit noon). The ACS control algorithm worked as expected, maintaining an inertially fixed orientation for the required orbit. A special view file was generated by FDF which predicted when TRMM would be in view of TDRS using both the High Gain Antenna (HGA) and the Omni antennas. However, the wrong maneuver start time was used to generate the special User Antenna View (UAV) file, so TRMM was not in view of TDRS with the HGA during one of the scheduled supports (Event #55). The HGA was used for all events scheduled and the Omni never had to be used. Due to thermal constraints with the VIRS instrument, it is not expected that this maneuver will be performed again.

4.2 Deployables

The Deployables subsystem has performed reliably. The HGA has been able to track TDRS, without problems, in the X and Y axes, even during Delta-V and Yaw maneuvers, and the solar arrays have been able to transition between solar tracking and feather modes without any problems. There has been one autonomous GSACE switch (A to B) that occurred on 99-003, which was the result of tight ACS FDC limits and not an actual problem with GSACE A. The only concern to date has been the possibility of bearing lubricant degrading in the -Y solar array drive, which has consistently experienced temperatures exceeding pre-launch life testing at high solar Beta angles.

4.2.1 Performance

The High Gain Antenna System (HGAS) is used as the primary means of communications and has operated with no anomalous behavior. During real-time Delta-V and Yaw maneuvers, there has been no loss of Radio Frequency (RF) lock while operating with the HGA. It remains feathered when out of contact with TDRS and during events with the Omni antennas. During the recovery operations of the GSACE switch/Sun Acquisition anomaly that occurred on 99-003, the HGA was able to successfully track TDRS while the spacecraft was in Sun Acquisition mode. The FOT monitors the glitch buffer for the X and Y axes of the HGA, which have not changed since launch, for motor degradation and signs of slippage.

The slewing of the solar arrays continue to be nominal during eclipse transition and maneuver operations, although there is one area of concern. The -Y solar array actuator temperature has peaked several times at approximately 41.5 °C (Figure 4.2-1), just below the Yellow High (YH) temperature of 42 °C, during the Beta angle of 48° (when the Sun has the best view of the shoulder hinge and the output flange of the Solar Array Drive Assemblies (SADAs)). This trend is a long-term concern because the actuator Penzane lubricant could degrade and evaporate if the bearing temperatures, which cannot be measured directly, are higher than expected. The life test temperature of the solar array drive motor is 37 °C. Thermal analysis predicts that for these exterior temperatures, the ball bearing interior temperatures within the actuator may be as high as 73 °C. Even a 10 °C increase in temperature is 100 times more likely to evaporate the lubricant and potentially cause undetected levels of metal particles, which could be magnetically attracted to the gears in the zero-gravity environment. Due to the nature of the telemetry downlinked and stepper motors, there will probably be no indication until a motor failure occurs and causes the spacecraft to transition into Sun Acquisition mode. Several measures have been considered because of the possibility of a potential solar array drive failure.

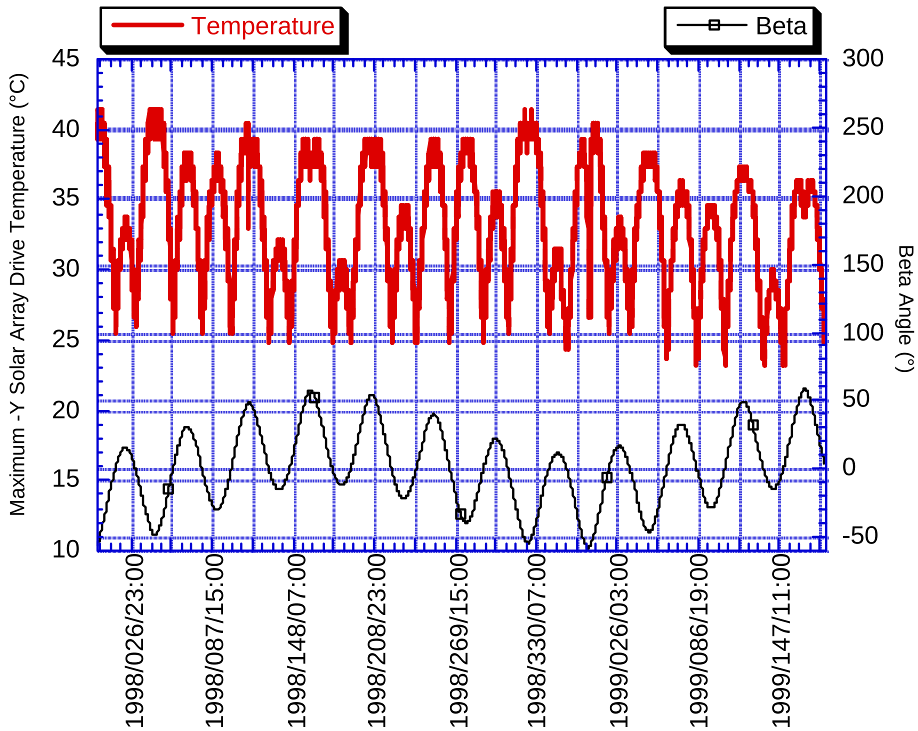


Figure 4.2-1 -Y Solar Array Drive Temperature and Beta Angle

In order to reduce the array duty cycle, the FSW group was asked to implement a solar array limiting scenario, in which the arrays would only be allowed to track between ±50° (originally ±130°). The feather position for both arrays would remain at 0°. After successful tests with the simulator, this plan was implemented on the spacecraft on 98-146 by loading ACS Table #76 (Solar Array Parameters). Unfortunately, during the first orbit in daylight, as the solar arrays reached the software stops during normal sun tracking, it was noticed that the ACS still sent rate commands to the SA drive motors. After reviewing the flight code, it was determined that during the time the arrays are limited, the ACS software computes the commanded velocity for the solar arrays before it limits the commanded position based on the software stops. As a result, the ACS commanded velocity is high, even though the actual velocity is zero, since the arrays are already at the software stop. The solar array drives were actually drawing slightly more current than they would if they were feathered or stopped, even though they were not actually moving. Since possible effects could not be confirmed through telemetry, it was unknown if the arrays were 'jiggling'. This would actually be worse for the array drive than the higher temperature condition it is experiencing. Solar array dithering was never experienced with the old stops of ±130° because the arrays never reached the software stops at any Beta angle. On 98-147, the original software stops were restored, and the FSW group was tasked with developing a software patch that would eliminate any possibility of this dithering effect.

It was felt that in order to fully document the power profile in this new configuration, one more test would be conducted at the maximum solar Beta angle prior to implementation of a new patch. On 98-161, the ±50° software stops were implemented for one orbit in order to obtain an accurate power profile. The results of this test are further discussed in the Power section of this document.

After looking at the ACS algorithm and reviewing several ideas, FSW determined that the addition of one software check requirement would solve the problem. Upon reaching the software stops, ACS would now set a global flag which disables SA process controlling, effectively duplicating array behavior while feathered. When ACS computes that the last commanded position is within a database specified tolerance, 0.51°, SA process controlling is re-enabled. At this point the commanded velocity drops down to 1 pulse per second (pps). On 98-349, ACS Table #76, with the software stops of ±50°, and the ACS RAM code patch were uplinked during the eclipse of 15:29 to 16:06. After verifying it was working correctly, by monitoring telemetry and dumping tables and memory, Table #76 and the code patch were written to EEPROM on 98-350 during the eclipse of 14:21 to 14:57.

On 99-003, two minutes after Delta-V maneuver #68 burn #1 completed and the ACS transitioned to Normal mode, FDCs #112 and 113 tripped sending the active GSACE to side B and the ACS mode to Sun Acquisition (Anomaly #71). Analysis showed, once the return to Normal mode occurred, the solar arrays began slewing to catch up to the new commanded position of 47° following the maneuver. Right as the arrays reached this value, the ACS computed a new commanded position of 50° which was the software stop. This caused the commanded velocity to drop to 1 pps. Since the arrays could not come within the 0.51° tolerance of commanded versus sensed position within two minutes at the 1 pps rate, FDCs #112 and 113 tripped (Figure 4.2-2). Four maneuvers were successfully conducted prior to this anomaly with the new configuration in place. The window of opportunity for this scenario to occur is very small, and is the reason this condition was not found in simulations and therefore included in the code patch tests.

Upon determining the anomaly was the result of the way that the ACS flight code was written, and not a solar array drive or GSACE failure, it was decided to switch back to GSACE A on 99-004. Before transitioning back to Normal mode on the next day, the old solar array software stops of ±130° were uplinked until further analysis could done for the new stops.

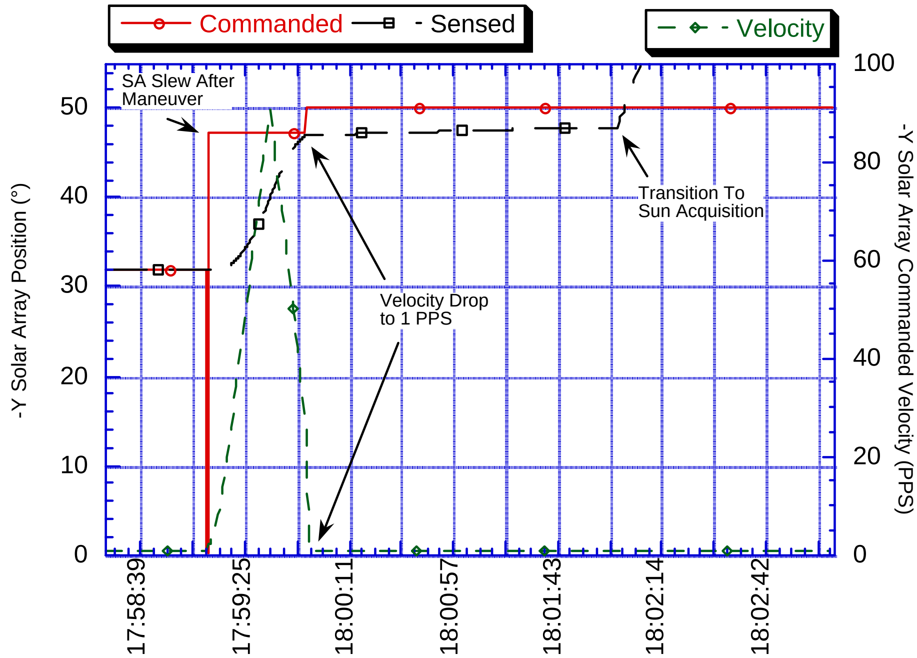


Figure 4.2-2 Anomaly #71: -Y Solar Array Position and Velocity

After performing tests with worst-case scenarios, where the commanded versus sensed position would be the greatest, it was determined that 12° would be a good tolerance for use by FDCs #112 and 113. On 99-040, the new tolerance and the ±50° software stops were uplinked in ACS System Table #76. However, this new FDC limit would only indicate a GSACE failure, but would not provide a warning if a solar array drive was slipping. This was important because the +Y and -Y solar array glitch buffer was no longer being updated since the arrays were no longer passing through 90°. Therefore ACS TSMs (#2-13) were created to perform the same task as the old FDCs. The TSMs would trip if they registered a difference of 0.51°, 5°, and 10° between the sensed and commanded position for two minutes. The action taken would be an event message. TSM #4 and 7 would be reset at the end of each day's spacecraft ATS load to ensure the TSM maximum message count would not be exceeded. Since the implementation on 99-047, these TSMs have tripped twice following Delta-V maneuvers.

Another possibility considered was parking the -Y solar array before it fails, in a known and safe position. Extensive power and attitude analysis was done by AETD to arrive at an angle of 30° to park the array. The other array would track between ±130° during daylight and feather at 30° during eclipse to minimize torque imbalances. However, power management would have to be done at certain Beta angles and seasons in Normal mission mode to remain power positive.

Analysis also showed that if the array failed in an unfavorable position, -50° to +30°, Sun Acquisition and Safehold may not be in a power positive mode after 36 hours, unless further actions are taken. A Readiness Review was held in June 1999 to make the decision on whether or not to park the -Y solar array. Since power management would have to be performed regardless of the decision, it was decided to continue tracking with the both arrays instead of introducing a new complex operation. Instead, emphasis would be placed on FOT training for solar array failure identification and early contingency steps. A checklist has been developed to aid Console Analysts.

The readiness review panel also considered an accelerated life test on the drive motor at a high temperature. Due to its cost and inconclusive evidence in determining whether the drive will fail, it was decided not to do the test.

Other actions might be taken for a possible array failure, such as opening up the PR survival heaters in Normal mission mode to prolong a power positive state in Sun Acquisition and Safehold (see PR section) and load-shedding such boxes as IPSDU-B.

When FDC #112 and 113 tripped on 99-003, RTS #20 started which switched the GSACE to side B. This was the only time GSACE B has been powered while on-orbit. The solar arrays operated nominally and the HGA was intentionally never fully configured to GSACE B. After verifying that the failover did not occur because of a problem with side A, a switch to the A side was done on 99-004. The switchover included checkout tracks of the SAs and the HGA and verification that the B-side relays were indeed opened.

There was one unusual behavior from the 99-003 anomaly in which the HGA potentiometer (POT) reading for the hinge toggled between the states of MOVING and DEPLOYED. Investigation proved that the HGA could not actually become undeployed, and the telemetry was attributed to the attitude position of Sun Acquisition, where the Sun was heating the potentiometer, which is sensitive to temperature, causing the discrete state to toggle. Once the Observatory transitioned back to Normal mission mode and systems returned to normal operating temperatures, this state returned to DEPLOYED and has stayed there ever since.

4.3 Reaction Control Subsystem

The Reaction Control subsystem (RCS) has operated without incident in support of the 98 Delta-V maneuvers which were performed from January 1998 through June 1999. During that time there has only been one item of interest, concerning LBS maneuvers, and it has no impact on operations. This will be explained in more detail in the thruster performance section.

4.3.1 Delta-V Stationkeeping Maneuvers

The 98 pairs of Delta-V stationkeeping firings which were planned through June 1999 are referenced as maneuvers #10 through 107. All of the maneuvers were nominal, with two exceptions that were not related to the RCS subsystem. Maneuvers #12 and 68 were not completed as a result of FDC test threshold violations. Maneuver #12 was the first full LBS thruster set burn of the mission. The maneuver aborted because the amount of initial body momentum in the pitch axis was not accurately anticipated in the thruster alignment modeling from pre-launch. For maneuver #68, the second burn of the pair did not execute because of an unrelated solar array tracking software change which had one small failure window which was not modeled in acceptance testing (see the Deployables section).

For the incomplete maneuver #12, the off-modulation of thruster #2 (+Pitch) did not occur before the 30 Nms FDC abort level was reached. As a result, the maneuver terminated 10 seconds into the planned 39 second burn (Anomaly #52). Later analysis showed the off-modulation (and corresponding momentum reduction) was just missed by a matter of a few control cycles. It was then decided that the 30 Nms maneuver abort limit was too tight, and the pitch momentum value in ACS System Table #73 was increased to 40 Nms. The maneuver pair was then successfully performed the following day (98-025) after collecting sufficient tracking data for an updated orbit determination. It was later decided to further increase the FDC abort level to 45 Nms, because trending analysis showed that the pitch momentum reached as high as 38 Nms during the second half of the LBS Delta-V maneuver pair. Since that time, there have been no recurrences and the current limits appear to be accurately set. The body rates are closely monitored each maneuver to ensure that no further adjustments are required, and the thruster alignments of both thruster sets are now well understood and are consistent.

Maneuver #68 was a planned maneuver pair of 41 and 24 seconds, the second of which was not performed (Anomaly #71). On 98-349, the solar array tracking software was modified due to concerns for the long-term health of the -Y solar array (see ACS and Deployables sections). The first burn for maneuver #68 was conducted routinely on 99-003 at 17:55:02. However, an FDC violation switched the controlling GSACE to the B side, placed the spacecraft in Sun Acquisition mode, and the second burn was not conducted. Maneuvers #64 - 67 had all been conducted nominally, without this violation occurring. Once recovery operations were complete, maneuver #69 was successfully conducted on 99-006 to restore the optimal orbit parameters. The next time the circumstances matched the same failure window was not until maneuver #100 on 99-147, which had new FDC limits in place by that time.

There were three changes to Delta-V maneuver operations over the timeframe of this report. The first item was a change in the maneuver schedule, the second involved the implementation of subsecond burn durations, and the third shortened the catbed heater warm-up duration. Starting with maneuver #74 on 99-029, maneuver scheduling was changed from an as-needed basis to an every 4th day basis. There is a requirement to have at least some contact time between burn pairs to ensure nominal conditions prior to executing the second burn. The uncertainty and frequent changes in planned maneuver times due to solar fluctuations resulted in frequent changes to the contact schedule and even occasional patch loads to the spacecraft, which is what ultimately drove the decision to change. By having the maneuvers on a known schedule, it was easier to get real-time coverage, and the engineering staff was able to plan their schedules better for weekend or holiday coverage. Unfortunately, the change made long term predictions of orbit position more difficult for field campaigns, because maneuvers tended to be biased to the top of the desired science collection orbit box. Since FDF felt too much risk would be introduced by planning maneuvers with varying target altitudes, it was finally decided to end the trial basis with maneuver #87 on 99-081 and begin planning maneuvers on an as-needed basis again. To alleviate the planning difficulties, FDF began delivering daily maneuver planning notices so that any fluctuation would be immediately known.

The other two changes in maneuver operations did not have any unforeseen effects. Beginning with maneuver #82 on 99-061, Delta-V maneuvers were performed without the limitation of maintaining integer second burns. All burns are conducted by counting down to zero from the required number of 8 hz counts, so this was no impact to operations. The new scenario was successfully tested with the dynamic simulator before implementing it on the spacecraft. Starting with maneuver #99 on 99-141, the turn-on time for the thruster catalytic bed heaters was changed from 91 minutes prior to the first burn to 45 minutes, in order to better accommodate the Power subsystem recovery during all solar Beta angles. This change was only made after extensive trending over all Beta angles and seasons, to ensure that the 32 °C pre-fire temperature requirement was not in jeopardy at any time.

4.3.2 Fuel Budget Analysis

Due to budget constraints and the probability of a TRMM follow-on mission in 2006, greater emphasis was placed in 1999 to develop a reasonable prediction for mission life remaining. Pre-launch fuel consumption predictions were calculated using a nominal regulated pressure of 170.0 psia. Observed data through June shows this value is closer to 167.7 psia. In addition, the FOT developed an analysis spreadsheet, in conjunction with the RCS Code 574 engineers, to better establish the relationship between average daily fuel consumption and the Schatten solar flux predictions, using curve fitting functions. The predicted Schatten values are periodically updated with the actual numbers, to better tune the curve being used. The initial fuel level was 890 kg. Using the predicted mission life spreadsheet updated through June 1999, the mission life is currently predicted to be 6.4 years from Launch (November 1997). This estimate accounts for the 63 kg of hydrazine required for an End of Life (EOL) orbit decay phase and the controlled re-entry, as well as residual fuel in the lines and tanks. Through maneuver #107, TRMM had used less than 174 kg of fuel, and still had over 716 kg of hydrazine remaining. The *TRMM End of Life and Controlled Re-entry Plan* will be developed by the FOT in conjunction with FDF and AETD in 2000, which will describe the EOL activities as well as subsystem failure triggers which could require a more immediate re-entry. The summary of Delta-V maneuvers performed through June 1999 is located in Appendix F.

4.3.3 Thruster / Valve Performance

Data from FDF indicates that the thrusters are providing 5% greater thrust than originally modeled before launch. In addition, the thruster misalignments are minimal, combining for a very efficient RCS. For example, none of the roll control thrusters has had to fire during any maneuver to date in order to compensate for thruster misalignments or for excessive external torques. For ISP burns, there is a small pitch misalignment, and the -Pitch thruster (#6) typically off-modulates 30% to 35% of the total on-time to compensate. For LBS burns, there is a similar pitch disturbance, but there is also a more gradual yaw torque. The +Pitch thruster (#2) typically off-modulates 15% to 20% of the time and the -Yaw thruster (#1) typically off-modulates 5% to 8% of the time to compensate.

The Catbed temperature performance also has behaved as expected, reaching a maximum level of approximately 600 °C during maneuvers. The Catbed heaters also have performed nominally. The heaters are turned on 45 minutes prior to each stationkeeping burn, but typically reach the minimum 32 °C requirement in less than thirty minutes, depending on the initial temperature due to sunlight. Furthermore, the expected post-maneuver thruster valve temperature rise due to soak back effects is only 10 °C on average.

Prior to maneuver #25 on 98-121, the on-board table (RTS) which controls the Catalyst Bed heater power-on was not enabled at the appropriate time (Event 35). As a result, the decision was made to power on both the A and B side heaters manually for the first time on-orbit, in order to ensure that the catbed temperatures would be above the 32 °C optimal temperature for thruster firings. The thrusters are qualified to fire at temperatures below that value for up to ten times, but there was sufficient time available to avoid that scenario in this case. Redundant verification and pass-plan notations were added in order to ensure the scenario would not be repeated, as part of the FOT’s continuous risk management program. The dual-heater configuration performed as expected, and the temperatures increased at a rate that was approximately 50% faster than one heater alone would have been able to accomplish.

During LBS maneuvers in which a long period of time elapsed since the previous LBS maneuver, the body momentum plateaus for a few seconds at a point approximately seven seconds into the burn, before resuming the expected trend profile. Once the thruster is commanded off at the control switching limit, the phenomenon is not seen again throughout the rest of the burn nor in the subsequent burn of the pair. One theory suggests that this might be the result of a small gas bubble which would enter the thruster at the seven second mark, presumably the travel time of the gas through the fuel line and thruster assembly from its point of origin. In general, for consecutive LBS maneuvers that have only a week or less between them, this phenomenon is much less noticeable, lending credence to the gas bubble generation theory. The source for the gas bubble generation is unknown. This phenomenon has had no effect on maneuver performance, as indicated by the FDF post-maneuver reports.

4.3.4 Tank Performance

Fuel tank pressures and temperatures have been nominal throughout the mission, averaging about 167.5 psia and 18.4 °C respectively. The propellant pressure remained constant throughout the burns at 165 psia on average, and returned to the pre-burn values of 167.5 psia following all maneuvers. The tank and pressurant heaters have experienced minimal on-time, due to the consistent temperature levels of the tanks. For example, the pressurant tank has seldom dropped below its heater set point of 23 °C. However, as the solar Beta angle increases, the pressurant tank temperature increases due to extended solar heating. The pressurant tank pressure value, which began at 3230 psia prior to Launch, reached a value of just under 2300 psia at the end of June, with the biggest drop of more than 100 psia occurring during the descent maneuvers. Utilizing the same spreadsheet which contains the solar flux predictions, blowdown mode will probably not occur until early 2003, although that will be recalculated on a regular basis.

4.3.5 Line Performance

The line temperatures were nominal during the first 18 months of operations. The fuel line temperatures decrease 4 to 7 °C on average as propellant flows through the lines. The internal and external line heaters continue to provide adequate thermal stability to the lines, with an observed duty cycle of close to 50% for the internal lines, with a setpoint of 23-24 °C. The only exception is internal line segment #5, which has experienced a temperature gradient of only 2.5 °C over the entire period. The external line heaters have an observed duty cycle of approximately 15%. Due to the location of internal line #8 at high solar Beta angles in the -X forward orientation, it has experienced extended solar heating, more than any other internal line (Anomaly #57). As a result, line #8 experiences the largest long-term temperature gradients of all the internal lines, and the highest peaks which are at 35.5 °C. There has been no impact to operations from these conditions.

4.4 Power Subsystem

Overall, the Power system has provided power to the spacecraft well within specifications. A Battery-2 cell anomaly has been the only impact to operations of this subsystem and this has been managed without degrading performance. The PSIB has operated as designed: monitoring and generating telemetry, and calculating SOC. The PSIB has had one code flaw for certain timer routines. The solar array’s power output degraded rapidly in the first few months, but has tapered to the expected age degradation rate.

4.4.1 Charge Cycles

The initial setting of the Power system charge profile was at Peak-Power-Tracking (PPT) with a Voltage/Temperature (V/T) level setting of 5 and a Charge-to-Discharge (C/D) level of 1.045. Due to the battery cell anomaly, the charge profile has changed since initially set at launch. After a few modifications (see section 4.4.2 and 4.4.7), the PSIB is currently configured to a C/D of 1.025, V/T level of 5, a step-to-charge of 24 amps, and step-to-trickle of 0.75 amps.

The solar arrays supply an average of 3400 W of power to the SPRU to maintain the spacecraft load and charge the batteries, which averages about 750 W. The batteries take over the observatory load during eclipse, maintaining 28 ± 7 volts on the Essential bus (see Electrical section). The batteries have been through 8609 orbital charge cycles from 98-001 through 99-181.

4.4.2 Cell Anomaly Investigations

On 98-028, Battery-2 Cell-1 voltage began hitting the YH limit (Anomaly #55) of 1.49 volts. The cell charges ‘in family’, along with other nearby cells, until it approaches the V/T limit. As the V/T limit is approached, the cell diverges sharply upward and reaches it’s peak in conjunction with the V/T limit. Once the limit has been reached, the cell returns to the charge cycle ‘in family’. See Figure 4.4-1 for a typical orbit profile of Battery-2 Cell-1 when compared to other battery cells and Figure 4.4-2 for the trend of daily maximum cell voltages.

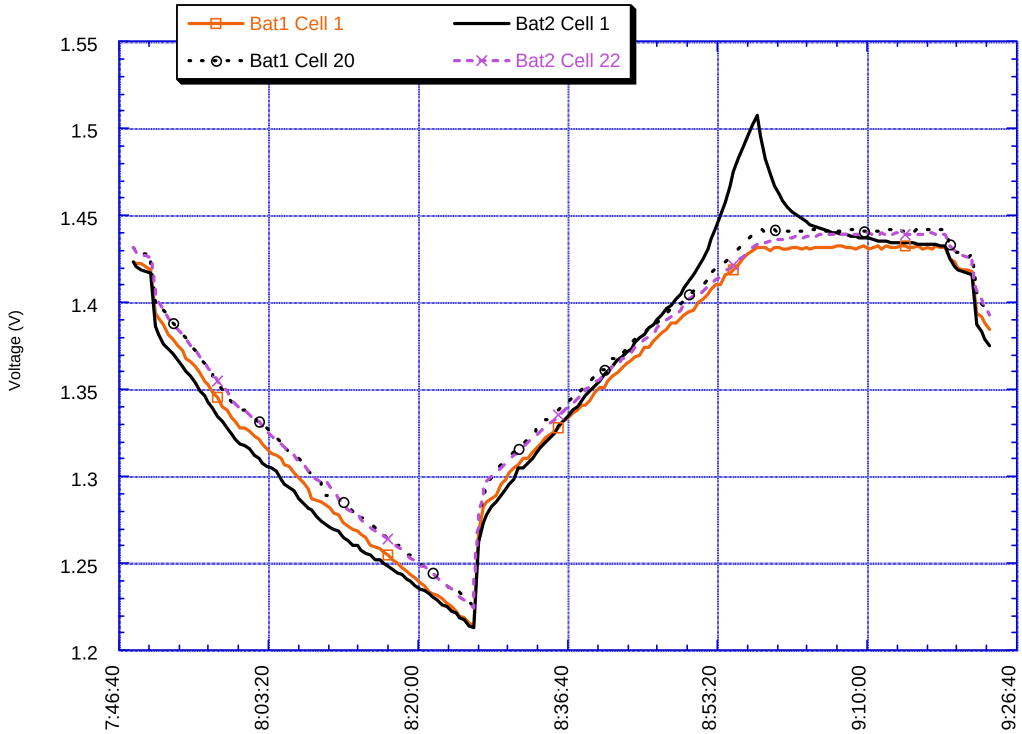


Figure 4.4-1 Orbit of Cell Voltages on 98-135

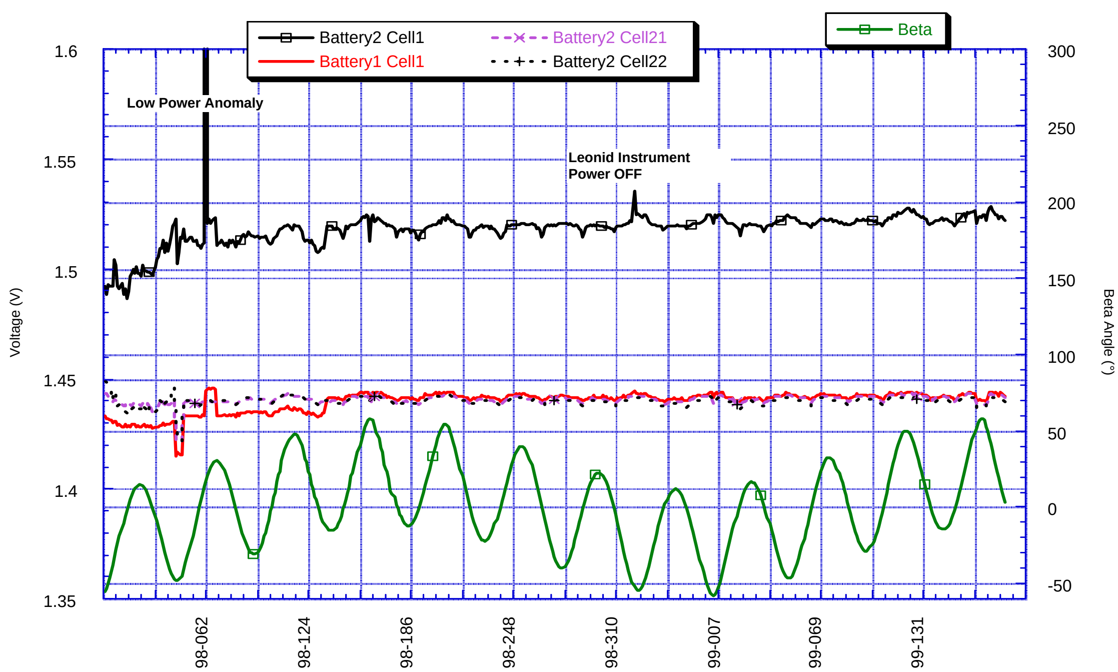


Figure 4.4-2 Battery Cell Voltage Maximums

On 98-043 at 13:59, with direction from Code 563, the V/T level was changed to 4 and the C/D was lowered to 1.03 to maintain a 100% SOC counter at the lower V/T level. All changes made during the report period for the anomaly are shown in Table 4.4-1. Lowering the V/T level was thought to clamp the maximum peak on Battery-2 Cell-1. These changes did not affect the peak, it remained at approximately 1.52 volts. Then, on 98-043/17:09, the auto-SPRU step-to-charge level was changed to a Constant Current (CC) of 48 amps (or 24 amps per battery) with a gain setting of 1. This did not affect the Battery-2 Cell-1 peak either, but did affect the ability of Battery-1 to reach 100% SOC. On 98-049 at 14:50, the V/T level was returned to 5, in order to maintain energy balance, and the step-to-charge setting was lowered to 24 amps (or 12 amps per battery) with a gain setting of 1. The charge current was chosen to lower the initial energy hit to the batteries that seems to aggravate the anomalous Battery-2 Cell-1.

Date	VT level	Step-to-charge setting	C/D setting
97-321 at launch	5	PPT	1.045
98-04 3/ 13:39	4	no change	no change
98-044/ 17:09	no change	CC 48A	1.03
98-049/ 14:50	5	CC 24A	no change
98-076/ 16:00	no change	no change	1.01
98-112/ 20:22	no change	no change	1.03

Table 4.4-1 PSIB Settings Changes for Cell Anomaly

On 98-062, PSIB B was turned on (see section 4.4.3 for the Low Power anomaly) to determine the cause of the Battery-2 Cell-1 voltage peaks. It was believed that the cell reading was a telemetry problem from PSIB A, since no normal method of reducing the cell's peak voltage was successful. On 98-068 from 17:47 through 21:29, dwell was turned on for Battery-2 Cell-1 on PSIB B and monitored. Both PSIB readings for the voltage of Cell-1 were similar. This eliminated the bad telemetry reading theory for PSIB A as the cause for the high readings on Cell-1.

On 98-076 at 16:00, the C/D was lowered to 1.01 so that the V/T level could again be lowered to V/T 4 and maintain energy balance. Code 563 believed that the Battery-2 Cell 1 high voltage peak would be reduced at the lower V/T level. The C/D level was returned to 1.03 on 98-112 at 20:22 due to the lower voltages (30 mV) seen on the battery full voltages and a few of the cells (Bat-1 Cell-1 and Bat-2 Cell-1) reaching Yellow Low (YL) limits (1.20 V). It was determined that V/T 4 would not be feasible with the current energy demand by the Power subsystem and the spacecraft.

4.4.3 Low Power

On 98-062 at 21:29, the Low Power TSM #2 activated the LOADSHED RTSs #2 and 15 (Anomaly #59). The TSM was tripped when PSIB B was turned on without changing the default gain setting of 16 (PSIB A is set to a gain of 1). The highest gain setting from both PSIBs is used when commanding the charge setting. The Power system was configured to be in a charge setting of 0.75 amps/per battery, the normal trickle charge setting once 100% SOC is reached. After 2 orbits in this configuration, both Battery-1 and 2 SOC dropped below 70%, activating RTS #2. The SPRU was then commanded to PPT. This caused Battery-2 Cell-1 to reach a maximum of 1.63 volts since the current was not limited to 24 amps (see section 4.4.6). The following orbit, the SPRU returned to its normal step-to-charge setting since auto-SPRU was not disabled in RTS #2.

4.4.4 Solar Array Performance

The solar array current and voltage are related to SPRU charge settings. During the PPT operation, voltage maximums reached 68 volts while the current reached 68 amps (see Figure 4.4-3). Once CC operations were implemented, the voltage increased to approximately 74 volts and the current relatively dropped to about 54 amps. The voltage, current, and temperature are influenced by Beta angle (see Appendix F) since the stops have been in place (see section 4.2).

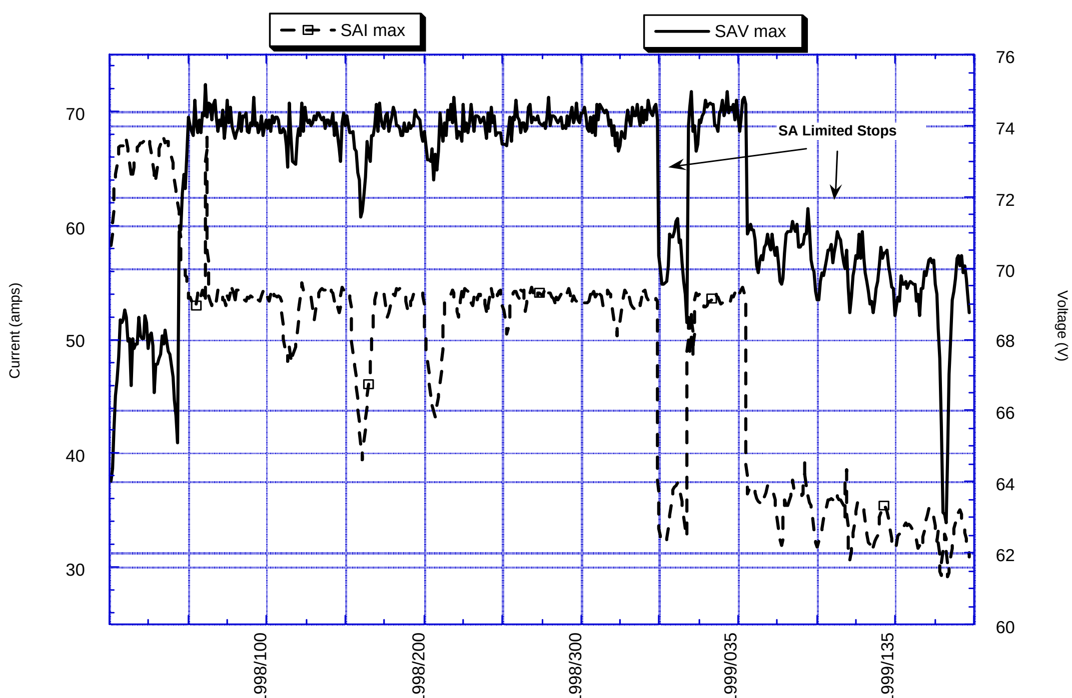


Figure 4.4-3 Solar Array Daily Maximum Current and Voltage

4.4.5 Solar Array Stops

On 98-146 at 15:32 the solar array software stops were changed to ± 50°, and on 98-147 at 21:40 the stops were returned to the original ±130° (see Deployables section). Figures 4.4-4 and 4.4-5 show the charge cycle with the stops in place versus one at the same Beta angle without the stops. The stops seem to increase the discharge time by only a few seconds, and there is also a decrease in the spike seen at the beginning of the charge period prior to the SPRU regulation.

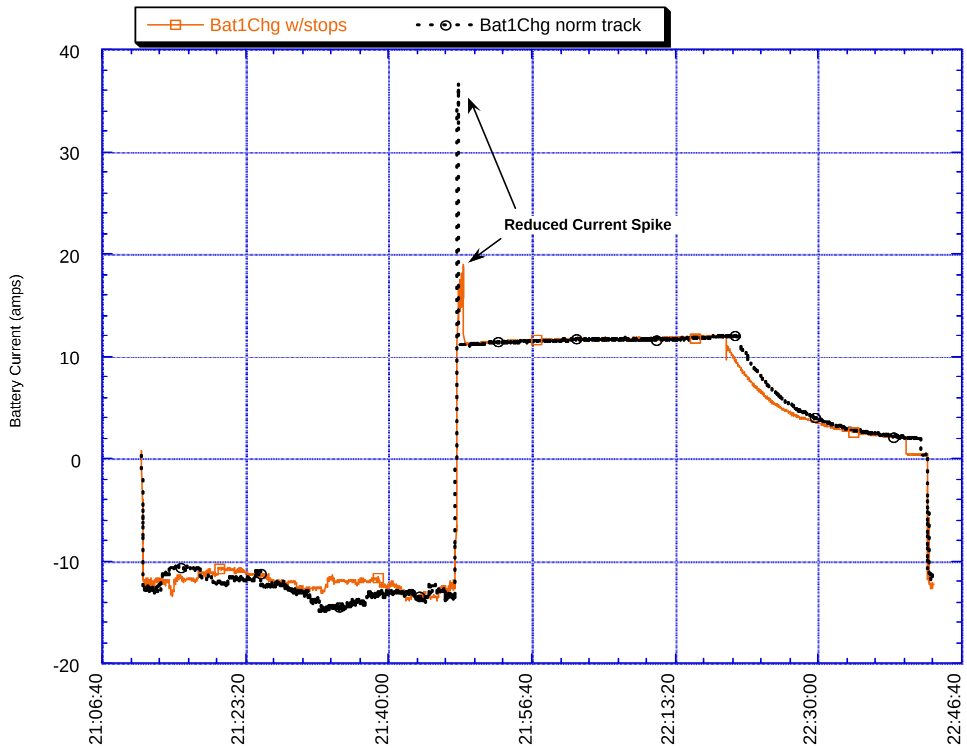


Figure 4.4-4 Charge Cycle at Beta 0° on 98-146

On 98-161 at 13:33 - 15:10, the solar array software stops were loaded again to observe the effects on the charge cycle at Beta +58°, the worst case shadowing and incidence angle with the solar arrays. As Figure 4.4-5 shows, the current was at the 12 amp setting within 40 seconds. The orbital eclipse, or discharge period, is increased by approximately 30 seconds, and the trickle charge time is reduced by 3.5 minutes. The reduction of trickle charge time is inconsequential at the high Beta angles, since there is nominally 20 to 25 minutes of trickle charge time.

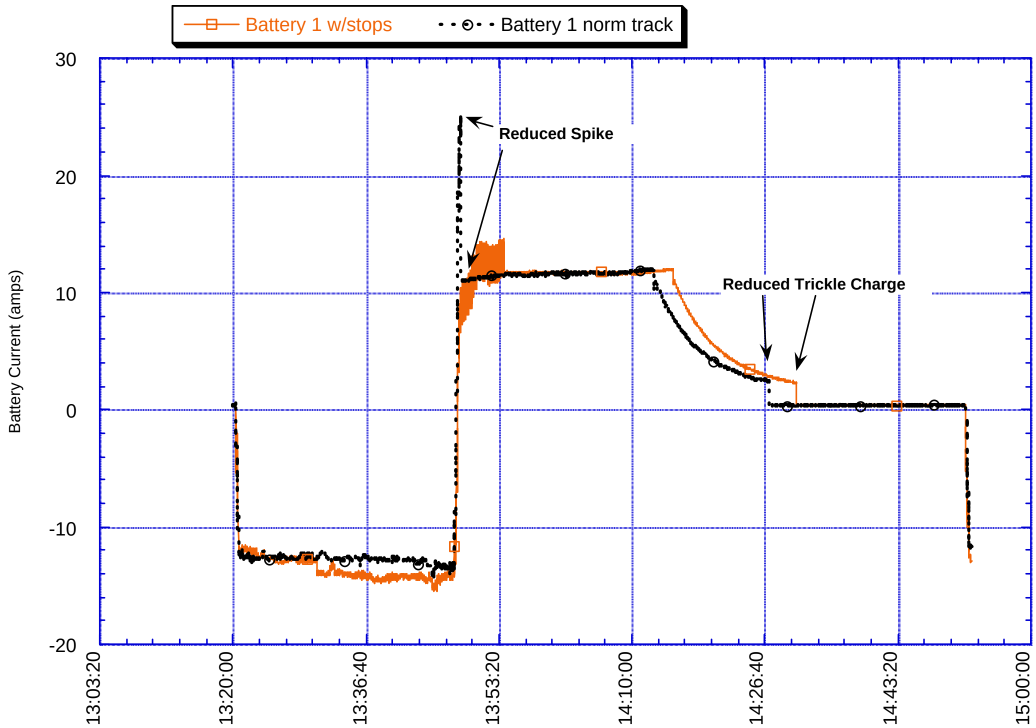


Figure 4.4-5 Charge Cycle at Beta 58° on 98-161

On 98-349, the ± 50° solar array stops were loaded permanently. The PSIB solar array temperature threshold was reduced to 32 °C, to more accurately match the cooling of the solar arrays from orbit day to eclipse with the reduced range of motion. Since the solar arrays have been limited, the Power system has performed nominally.

4.4.6 TSM and RTS changes

On 98-162, a modified RTS #2 (LOADSHED) and new RTS #13 (SPRUconfig) were uplinked to the spacecraft. The SPRU commands were removed from RTS #2 and placed in RTS #13. RTS #13 disables auto-SPRU and commands the SPRU to V/T 5, constant current charge mode of 24 amps (12 amps per battery). This will reduce the stress on Battery-2 Cell-1 and match the normal charge operations more closely.

On 98-181 at 14:11, TSMs #31-34 were uplinked to the spacecraft to monitor the End-of-Day (EOD) SOC. The limit is currently set at 95% and once the limit has been reached, RTS #13 will be started. This will prevent a load-shed of the instruments if the SPRU is mis-configured and give early warning to a possible battery charging problem.

4.4.7 SOC Counter Anomaly

On 98-171, the batteries did not achieve 100% SOC every orbit of the day for the first time. The trend repeated each time the spacecraft was close to Beta 0°. The undercharge coincides with an additional load seen on the Non-Essential bus. This was seen as a benefit to the batteries, since the PSIB will allow extra charge with C/D ratios of 1.04 and above to 'catch up' to 100% SOC. If the trend of lower C/D were to continually degrade the SOC counter, the charge profile would be adjusted.

On 99-062, the batteries did not achieve 100% SOC for any orbit of the entire day. The SOC counters reached EOD low values of 96.02 and 95.34 for Battery-1 and Battery-2 respectively. On 99-071 (Battery-2) and 99-073 (Battery-1) the batteries recovered. During the next few Beta 0° crossings, the SOC counters remained below 100% for days at a time. On 99-137 at 16:34, the EOD counter for Battery-2 fell below 95% to 94.990 (Anomaly # 72) as anticipated. This caused TSM #32 to start RTS #13 thereby disabling auto-SPRU. TSM #31 executed RTS #13, when Battery-1 EOD SOC fell below 95% on 99-138 at 06:17. On 99-138 at 15:49, with the direction of Code 563, the C/D was changed to 1.02 to allow the SOC counters to recover. On 99-155 at 14:32, the C/D was raised to 1.025 to match the current orbit charge profile.

4.4.8 PSIB Orbital Status Timer Anomaly

The orbital status timer stopped incrementing on 99-138 at 07:27 (Anomaly #73). After investigation, it was determined that the subroutine that resets the orbit status (day/night flag), and increments the time in day and time in charge, had stopped being called. The timer subroutine compares the upper and lower words separately with the PSIB clock (tick counter) words. If both timer words are lower, the tick counter plus 5000 are then loaded to the orbital status timer words. The anomaly occurred when the tick counter was loaded to the orbital status timer, then the tick counter rolled over prior to the comparison. Since the lower timer word was an extremely high number, the comparison failed and the orbital status timer stopped incrementing. This affected the EOD, End-of-Night (EON), and Amp-Hour counters. Three solutions were determined; reset the PSIB, reset the orbital status timer by command, or to allow the next rollover (every 9.9 days) to possibly fix the timer. Resetting the orbital status timer by command was determined to be the least risky and most effective. The orbital status timer was restarted on 99-154 at 14:10, by sending a hex command, provided by FSW (CCR #49), to the PSIB that reset the lower word to zero. The next comparison between the tick and orbital status timer words passed the PSIB logic and the timer was restarted. Many routines in the PSIB software use this same logic. FSW has been tasked to patch the PSIB software to correct the eleven critical logic routines (CCR #50).

4.4.9 Trending

Many aspects of the Power system are affected by Beta angle due to the change in eclipse durations and shadowing effects on the cold side of the spacecraft. The temperature of both batteries climbs as Beta 0° is approached and falls as maximum Beta angles are reached (Figure 4.4-6). The temperature swing with Beta angle is approximately 4 °C, with Battery-1 varying between 10.8 - 6.8 °C and Battery-2 varying between 12.2 - 8.4 °C. Orbital temperatures vary about 2 °C between eclipse and sunlight. Battery-2 Cell-1 peak voltage climbs above 1.52 volts (the maximum nominal peak is 1.528 volts) at high Beta angles (Figure 4.4-7). The battery full-voltage maximums and minimums are also affected by Beta angle (see Appendix F).

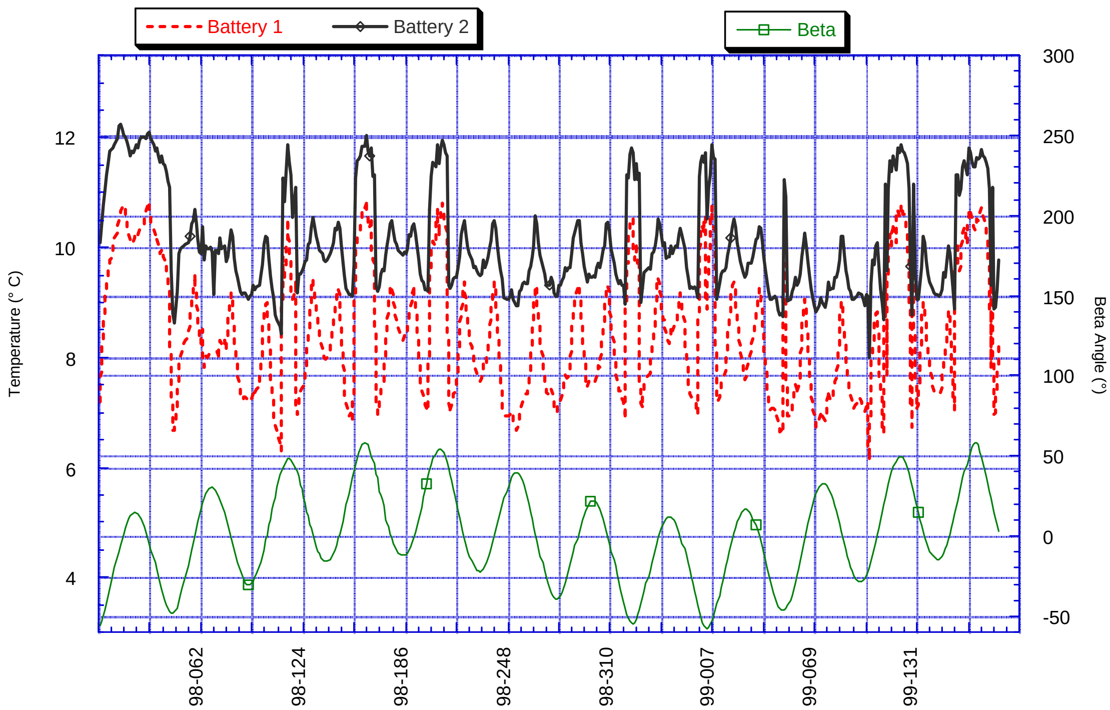


Figure 4.4-6 Battery Temperatures in Relation to Beta Angle

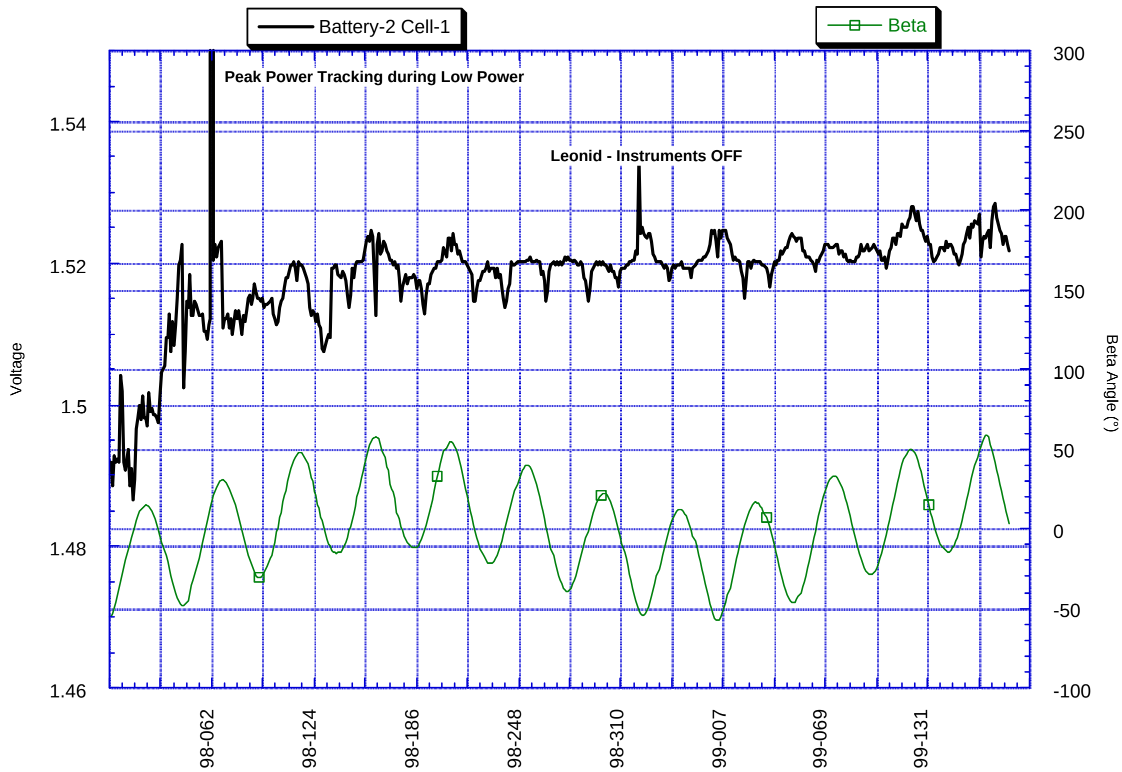


Figure 4.4-7 Battery-2 Cell-1 Voltage in Relation to Beta Angle

4.5 Electrical Subsystem

The Electrical subsystem has operated nominally for the past 18-month period. All instruments were powered on successfully, after being powered off four times due to Load-shed, Sun Acquisition, Leonid Storm, and the GSACE Switch/Sun Acquisition (see corresponding sections for more details).

The Non-Essential bus current remains stable with an average current of approximately 16.7 amps. The average maximum current is about 22.5 amps with peaks of up to 24.8 amps, as shown in Figure 4.5-1. The maximum current peak is higher than the YH limit of 25 amps, but lower than the 50 amps Red High (RH) limit. This violation of the YH limit corresponds to days on which Delta-V maneuvers are performed at certain Beta angles; the Catbed heaters draw current from the Non-Essential bus.

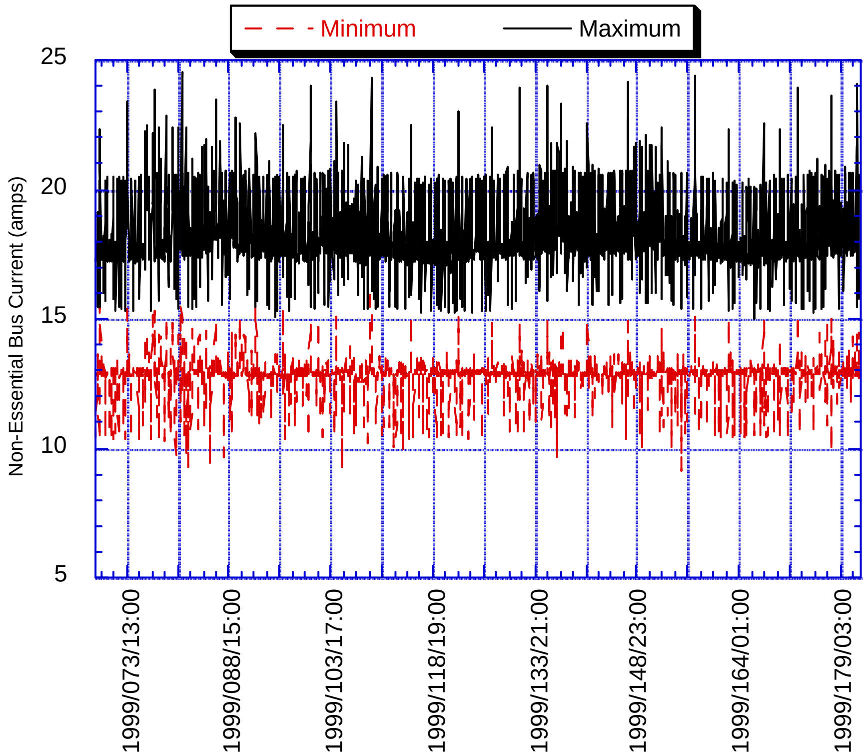


Figure 4.5-1 Non-Essential Bus Current

At high Beta angles, the average Essential bus current could reach as high as 7.4 amps. At higher Beta angles more current is drawn off the bus; an example of such current drawing load is the RCS heaters. The average Essential bus voltage has remained constant between 30 and 31 volts, increasing as the Beta angle reaches maximum values of ±58°. The Essential bus voltage, however, drops during Delta-V maneuvers, since more power is required for this activity. The Essential bus voltage profile changed on 98-043, when the maximum voltage decreased by one volt. It corresponds to Power subsystem configuration changes in response to the Battery-2 Cell-1 voltage anomaly (Anomaly #55); see the Power section for more information. The Essential bus current and voltage plots are shown in Figures 4.5-2 and 4.5-3, respectively.

The only outstanding issue related to the Electrical subsystem involves the CERES instrument. The CERES instrument +15 V voltage converter is failing, and in order to understand the situation, power to the instrument is being cycled at various time intervals. The cycling of power to the instrument has not shown any visible impact on the Electrical subsystem so far. Although no adverse impact is expected, the investigation of the long term effect will continue. The LaRC CERES instrument team has requested that the instrument be removed from load-shed. The instrument electronics will operate even when the converter stops regulating the current as a result of its failure. It is believed that the electronics might fail if power is removed and restored at the full bus current (see CERES section for more details). The instrument at the time of this report remains powered off except for specific testing purposes or activities.

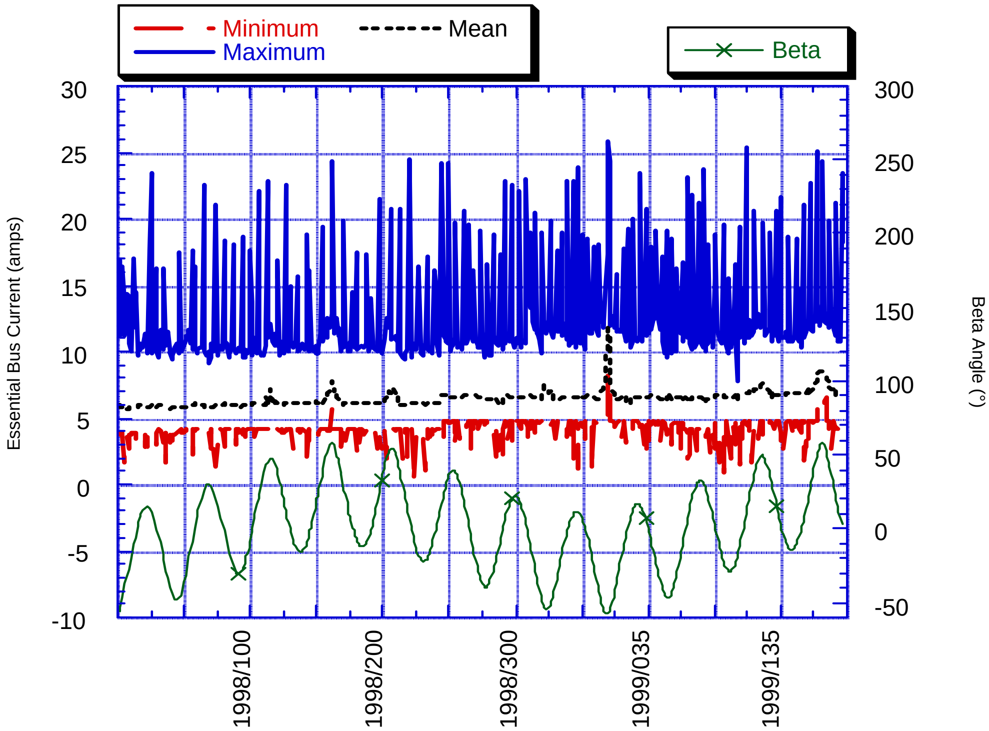


Figure 4.5-2 Essential Bus Current and Beta Angle

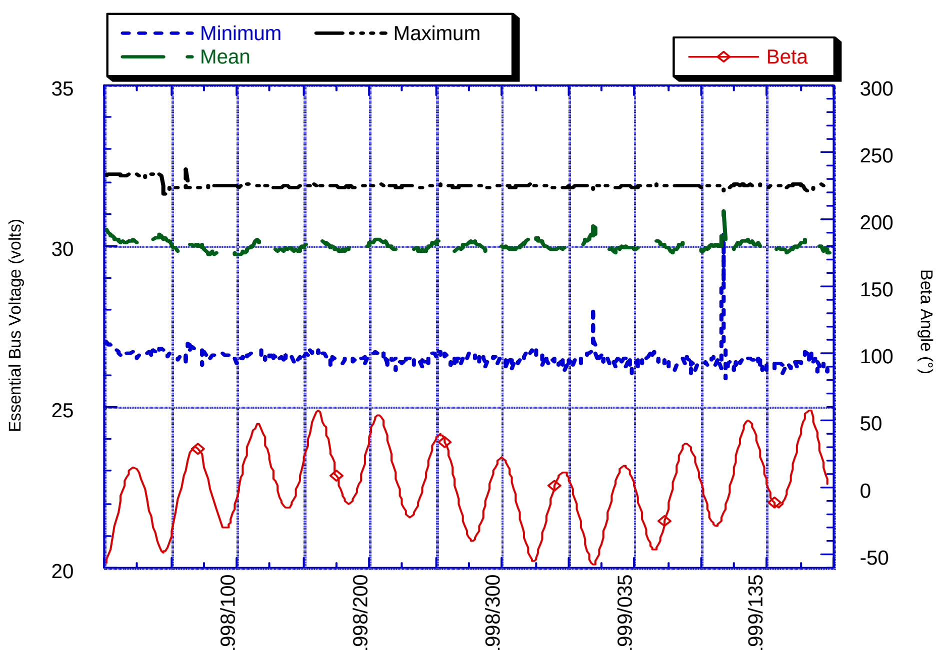


Figure 4.5-3 Essential Bus Voltage and Beta Angle

4.6 Thermal Control Subsystem

The Thermal Control Subsystem (TCS) has operated as expected. For thermal performance on specific subsystems, see the related sections. The biggest influence on the thermal behavior is the Beta angle cycle (see Figure 4.6-1). The location of boxes on the spacecraft is another factor in temperature variations. This is true especially in terms of heat provided by other components, as well as heat gained from sunlight exposure.

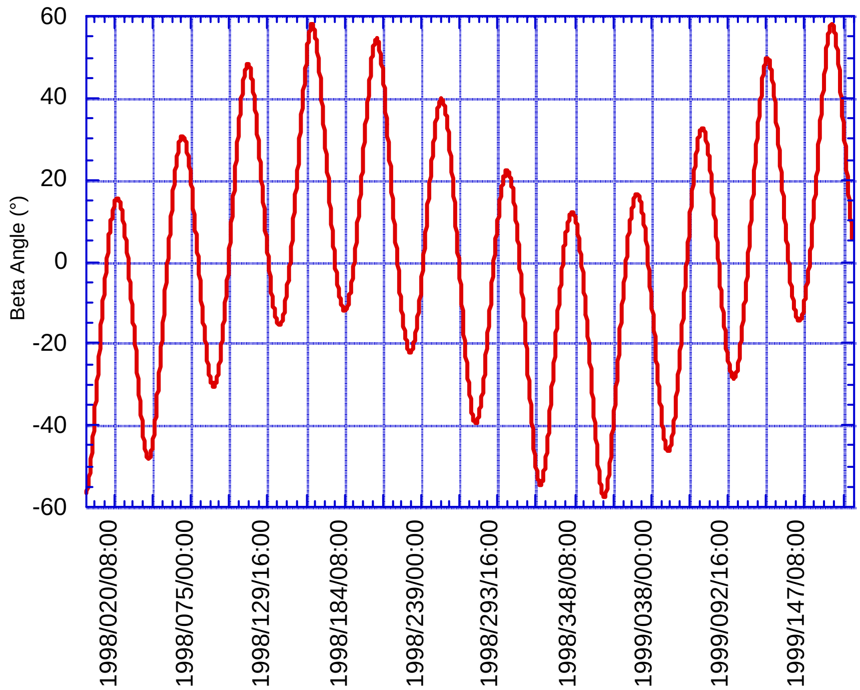


Figure 4.6-1 Beta Angle (Jan 1998 - June 1999)

There have been no heater failures of any kind. All elements, including thermostats, have performed well, as plots of the duty cycles and comparisons with the expected setpoints have shown. Survival heater operation was verified during the two Sun Acquisition anomalies mentioned in earlier sections. There have been no shorts in thermistor circuitry, and all telemetered points are well within the early-orbit checkout ranges which were incorporated into the ground system database. The electronics boxes have shown nominal temperatures, and it is an indication that the heat pipes, which are located beneath the boxes, are transferring heat properly. The +Y side of the spacecraft is maintained thermally cold, due to periodic 180° Yaw maneuvers. Trended temperatures have shown thermal stability, which is a good indication that the louvers located on the +Y and +YZ panels of the LBS are operating nominally. Unfortunately, there is no direct telemetry to indicate louver blade actuator operation. Thermal conditions during the 99-003 anomaly (Anomaly #71) have been the coldest the subsystem has experienced since launch. Also, a series of inertially fixed maneuvers were performed in January and

September of 1998, which provided a rare opportunity to monitor temperature changes under such conditions. The fuel line temperatures are closely monitored on Delta-V maneuver days. The Solid State Temperature Controllers (SSTCs) have also been operating nominally.

One item of interest is the +Y Solar Array temperature behavior. The temperature is well within limits, but has experienced minor temperature fluctuations which are somewhat unusual since that side of the spacecraft is maintained thermally stable. Until 98-276, the minimum and maximum daily temperatures were consistently maintained between about 9.5 °C and 13.5 °C, respectively. After day 98-276, the daily maximum dropped sharply to about 10.5 °C, where it remained until about 99-050. From that point on, the maximum has fluctuated gradually between 10.5 °C and 15 °C. This behavior appears to be independent of the solar Beta angle, as it should, since the +Y side of the spacecraft is kept out of direct sunlight. There has been no impact to operations from these fluctuations.

High temperature conditions experienced by the -Y SA drive remains a serious concern, and monitoring is still in progress (see Deployables section for more details). Some preliminary research is being conducted to determine the feasibility of pitching the spacecraft during extended Sun Acquisition periods (i.e. if the solar array drive fails) to limit duty-cycling of the PR survival heaters (see Power, ACS, and PR sections). The thermal effects of the new configuration on other instruments and systems is a concern, and all efforts are being made to understand and assess these effects, if any exist.

4.7 Radio Frequency/Communication Subsystem

The Radio Frequency/ Communication (RF/Comm) subsystem has performed well, with no major anomalies. The spacecraft has been communicating with a strong signal and has not lost any data due to on-board communication problems.

4.7.1 System Behavior

RF Interference (RFI) and false locks have been experienced periodically as expected. RFI causes intermittent dropouts but has had no major impact to operations. False locks are usually experienced on the redundant transponder (XP) and cleared with forward reacquisitions, when performed. Generic late acquisitions (<2 minutes) have been experienced, as expected, and have not caused any data loss. They have been successfully cleared with forward reacquisitions, some requiring more than one. No late acquisitions have been tied to the transponders or communication signal, and the majority of them have occurred during TDW events, equally distributed across both antennas. Numerous blind acquisitions have also been performed successfully on all four TDRS satellites.

The anomalous behavior experienced with the forward signal of TDS only lasted for the first 50 days of 1998 (Anomaly #58). The behavior appeared to affect the command lock most of the time, intermittently dropping lock during events, sometimes repeatedly. It also affected the receiver and Pseudo-Random Noise (PN) long code locks occasionally and would cause the transmitter to transition to non-coherent mode until the forward locked again. This was experienced with both transponders and, in general, indicates possible PN code problems (Automatic Data Processing Equipment (ADPE), EPV, etc.). The occurrences ceased once values were increased on the WSC ADPE on 98-050, though it has not been determined whether that was the source of the problem.

The uplink frequency remains 207694254 dHz. Thus far, the updates to the NCC database in January 1998 have been the only required ground frequency adjustments; performed to account for the aggressive behavior of XP-1. The XP-1 frequency has recently settled to approximately 700 Hz ahead of the uplink, drifting a total (excluding adjustment) of 1700 Hz. XP-2 has been gradually approaching the uplink, now approximately -700 Hz. The frequencies exhibit a strong dependence on the Temperature Compensated Crystal Oscillator (TCXO) temperature (see Figure 4.7-1). The reason for the larger variation of the XP-2 frequency is unknown at this time.

The transponder temperatures are showing obvious dependence on the Beta angle, varying sinusoidally with it. The fluctuation of XP-1 is approximately 5.5 °C, while XP-2 is 1.5 °C warmer overall and fluctuates 6.5 °C. The temperatures reach the maximums when the Beta angle reaches 35° (absolute), remaining relatively steady until it again falls below that, and the minimums occur at 0°. Components are also 1 °C warmer when traveling in the -X direction.

4.7.2 Operations

The communication signal can still be, or remains, acquired up to 2 minutes after the HGA reaches the software stops (proven during EOC), which allows slightly more flexibility in times of tight time constraints. There have also been no communication problems during any of the Yaw or Delta-V maneuvers.

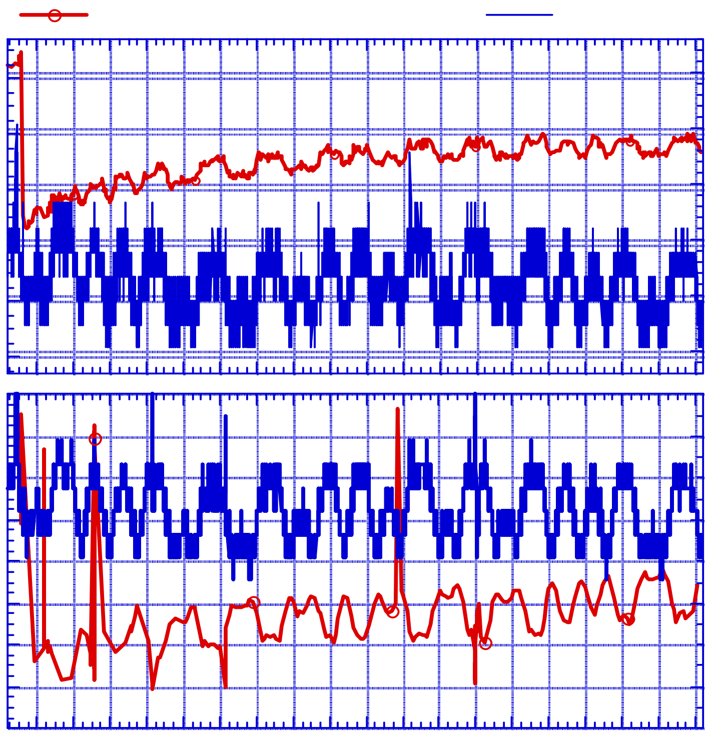


Figure 4.7-1 Transponder Frequency Behavior

The XP-1 frequency continues to be trended once a day, using coherency switches. XP-2 is now trended Monday, Wednesday, and Friday, continuing to use the non-coherent low-rate events, to attain a more accurate record of the behavior. Local Oscillator Frequency (LOF) reports are received from FDF every Wednesday, for the previous week, and are used for long-term trending.

It has been determined that TRMM experiences similar "forgetting" behavior with the frequency offset commanding as seen on the Rossi X-Ray Timing Explorer (RXTE). The offset is performed upon acquisition but lost upon deacquisition, and would have to be executed from the AOS/LOS sequences if required. Offsetting the frequency has not yet been necessary but may become so if signal quality decreases (such as intermittent dropouts, experienced periodically in the past with 1/4 kbps events, becoming more frequent).

4.8 Command and Data Handling Subsystem

The Command and Data Handling (C&DH) subsystem has met all requirements. There have been no hardware failures, and the 1773 optical bus and memory cards are behaving as expected under the atmospheric conditions. The software has operated as intended, with the error detection code registering several known anomalous occurrences.

4.8.1 Flight Hardware

System performance has been nominal, operating on the B-side Frequency Standard (FS) and Clock Card.

The 1773 optical busses have been experiencing an overall average of slightly less than three retries per day: the spacecraft bus (XS) experiences 1 per day, the instrument bus (XI) experiences 3 every 2 days, and the ACS bus (XA) experiences 1 every 4 days. Most retries have occurred in the South Atlantic Anomaly (SAA) Region (see Figure 4.8-1 for the geolocation plot) and none have resulted in any spacecraft anomalies.

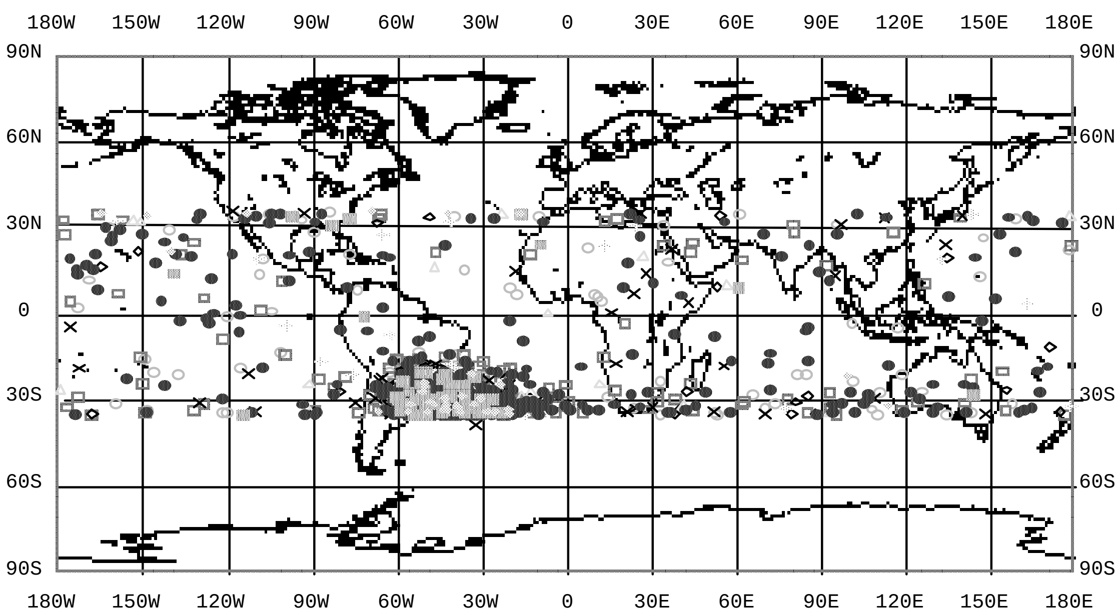


Figure 4.8-1 Geolocation of All 1773 Bus Retries

The 1773 instrument bus has experienced several retry errors from PR over this period. There is an apparent trend, but nothing definite has been determined at this time. These errors have not caused any interference to operations.

Memory Scrub (MS) single-bit errors have been experienced at a rate of 55 per day (Anomaly #4), and multi-bit errors have been experienced regularly at the average rate of 1 every 3 days (Anomaly #33). These values indicate that the bulk memory is less vulnerable to upsets, but that they have more of an effect when they occur. Trends indicate that the majority of the initial hits were experienced on the latter half of the memory cards (8 to 14), and now have shifted to the first half (1 to 7). The reason for this behavior is unknown at this time.

The FS has shown a strong negative drift, with the rate magnitude increasing steadily by approximately 0.5 µsec per day. The trend is clearly linear, though variations are observed due to the fluctuating temperature (due to Beta angle). The FS drift is still allowed to increase to -5 µsec/hr before adjustments are made. It can be turned positive by overcompensating with adjustments, but ultimately returns negative.

There has been another occurrence of an unexplained jump in the FS drift rate. On 98-360, the drift rate jumped from -2 µsec/hr to -5 µsec/hr, without being adjusted, and continued with its normal behavior. There was no apparent cause, but investigation continues into possible explanations.

The component temperatures have shown a distinct, direct dependence on the Beta angle behavior, fluctuating approximately 8 °C over a cycle. The components are 1 °C warmer when flying in the -X direction than when in the +X direction. The Spacecraft and ACS processors are 11 °C warmer than the baseplate and Frequency Standard. The temperatures reached their maximums once the Beta angle reached approximately 30° (absolute). As the Beta angle exceeded this, the temperatures remained steady until the Beta angle once again dropped below 30°.

4.8.2 Flight Data System

The Flight Data System (FDS) subsystem has performed nominally with no major anomalies. No capabilities have been added or removed, and no code patches are installed at this time.

4.8.2.1 System Behavior

The Software Bus (SB) has detected numerous erroneous packets delivered over the 1773 bus. These are expected occasionally due to the VIRS and TMI instruments generating packets with Invalid Stream Identifications, caused by known anomalies within the instruments. The VIRS housekeeping indexes become corrupted (indicated by an instrument warning message #20) and improper data is entered into the packet; the stream Id field in this case. This passes the XS 1773 validation but is rejected by the software (Anomaly #26). The TMI exhibits a behavior in which it places improper data in the header (and therefore the stream Id field) and data fields of two consecutive scan packets. These pass XI 1773 validation but are then rejected by the software, causing the next (third) packet to be improperly timetagged and also rejected. This accounts for the trio of software errors seen with this occurrence (Anomaly #40).

The Framer (FR) task has flagged errors being delivered from the ACS. These are hard errors on the bus that were not detected by the 1773 hardware Manchester coding but were detected by the FR frame validation (Anomaly #47). A similar hard error was seen on RXTE during bus-buster testing, but never on orbit.

The Telemetry Output (TO) task regularly restarts the Q-Channel telemetry due to an underflow condition experienced when trying to output a single frame (as opposed to the usual pair of frames - Anomaly #29). This occurs regularly (1 every 2 days) when performing playbacks and retransmissions and was encountered during Comprehensive Performance Testing (CPT). An operational constraint (requiring a ground system software modification) was determined necessary to inhibit it, but since no data is lost during the restarts, the implementation of the constraint has been deferred.

The Time Code (TC) FLYWHEEL anomaly (Anomaly #51) still occurs regularly. This has had no apparent affect on operations to date and has not been experienced on the ACS processor. Most of the flywheels have occurred below the equator, with approximately half of all of them occurring in the lowest 10° of the orbit (25-35° Latitude) which seems to indicate some geolocation dependence (see Figure 4.8-2). These incidents also seem to occur in timing clusters, with several happening close in time and then stopping for a period. The cause has not yet been determined, but the behavior does not appear to be affecting any component of the spacecraft. Dwelling is being used to track the behavior. The spacecraft processor TC Correlation Flag also toggled to False for a single update (Anomaly #63). This is an expected occurrence and is believed to be related to the TC FLYWHEEL anomaly.

The data bandwidth was exceeded on 98-065, causing approximately 2800 packets to be dropped during a 1/4 kbps event (98-065 - Anomaly #61). This was due to several extra data sources being sampled at once: dwell was enabled for the spacecraft processor and both PSIBs were powered ON. This is also believed to have caused 26 PR packets to be dropped (Anomaly #62) during this same period. An overflow also happened during the Sun Acquisition on 98-115, causing an undetermined number of packets to be lost.

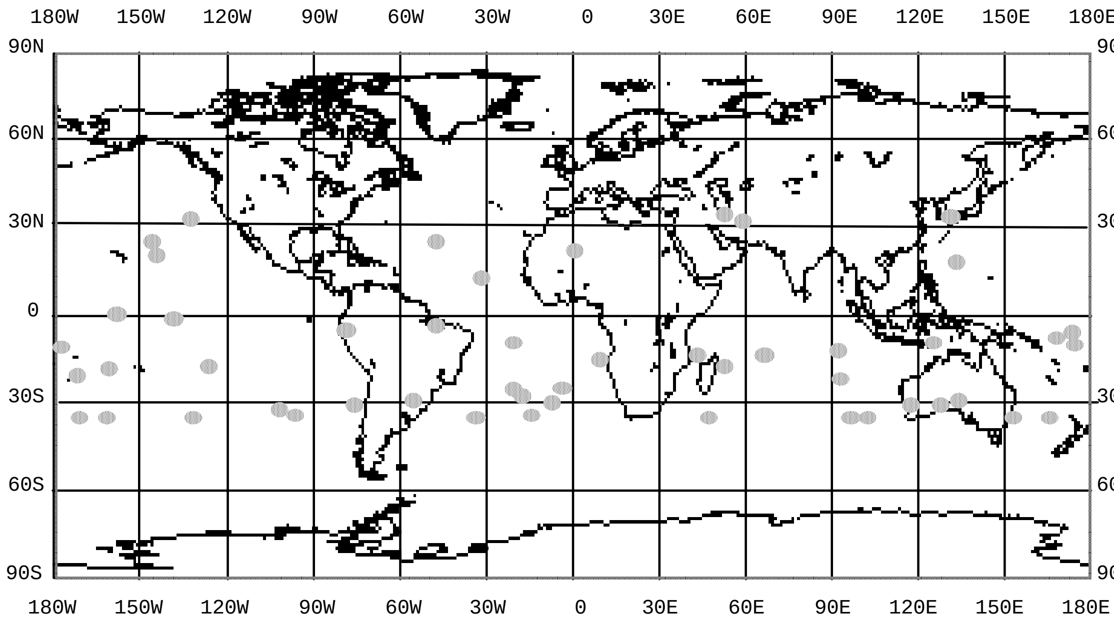


Figure 4.8-2 Geolocation of Flywheel Occurrences

The MS task occasionally misses an update with the Health&Safety (HS) task (registering NOT PRESENT) when releasing a large dataset (Anomaly #68). This is due to the Central Processing Unit (CPU) utilization by the DS task in these cases, and the non-critical classification of the MS task (only non-critical task). It has not caused any interruptions in operations, though if any other task were to miss a bus check-in the processor would warm start.

4.8.2.2 System Modifications

The TSMs have been modified several times in order to account for on-orbit behavior. TSMs #31-34 and RTS #13 were added on 98-181 to reconfigure the PSIB in the case of an incorrect charge configuration (see Power section). Also, TSMs #35-37, as well as RTS #34, were added on 98-260 to monitor CERES for anomalous voltage to avoid damaging the instrument, and the rest of the spacecraft, in case of a converter failure (see CERES section).

In an effort to make cold start recoveries more efficient, numerous updated RAM tables are being written to EEPROM. The DS Filter Tables (#68 and 69) have been the only ones completed to date (see Appendix E for a table load summary). Further copies are pending the outcome of the CERES exclusion from load-shed decision.

The Launch DS filter table (#68) was uplinked to record the ACE A 8 Hz data, to gather more of the IRU information during the maximum SA jitter period in June (see the ACS section). This table will be loaded to one of the open DS filter table slots (#70) so that it can be used more easily in future anomaly investigation.

The DS Quota table (#73) was adjusted on 98-097 to reallocate more recorder space to the VIRS instrument, to account for the extra data collected when night-mode transitions were stopped. It changed the individual recorder times for the science Virtual Recorders (VRs) to 211 minutes.

One leap second adjustment has been performed successfully at 99-001/00:00:00. It was performed from the stored ATS load and was confirmed the following event.

The Universal Time Correlation Factor (UTCF) is still allowed to drift the range of the 1 msec requirement (~900 μsec) before adjustments are made, to allow trending of the frequency standard drift.

5. Observatory Instrument Operations

All the instruments, with the exception of CERES, have operated in a nominal manner since launch. CERES had to be powered off on 98-244, due to a problem with a voltage regulator and is currently only powered on for ground validation testing. The other instruments have been powered off four times due to the following anomalies: Low Power on 98-062 (see the Power Section), Sun Acquisition on 98-115 (see the ACS section), the Leonid Storm on 98-321, and GSACE Switch/Sun Acquisition on 99-003 (see the Deployables and ACS sections). Since CERES had been powered off on 98-244, it only was affected by the anomalies on 98-062 and 98-115. For exact times when the instruments were powered off, see Appendix F. Due to a TSM misconfiguration, the LOADSHED RTS did not autonomously turn off the instruments on 99-003. They were turned off manually by starting the LOADSHED RTS. There was no known damage to the instruments. Figure 5-1 below shows the location of the instruments on the Observatory.

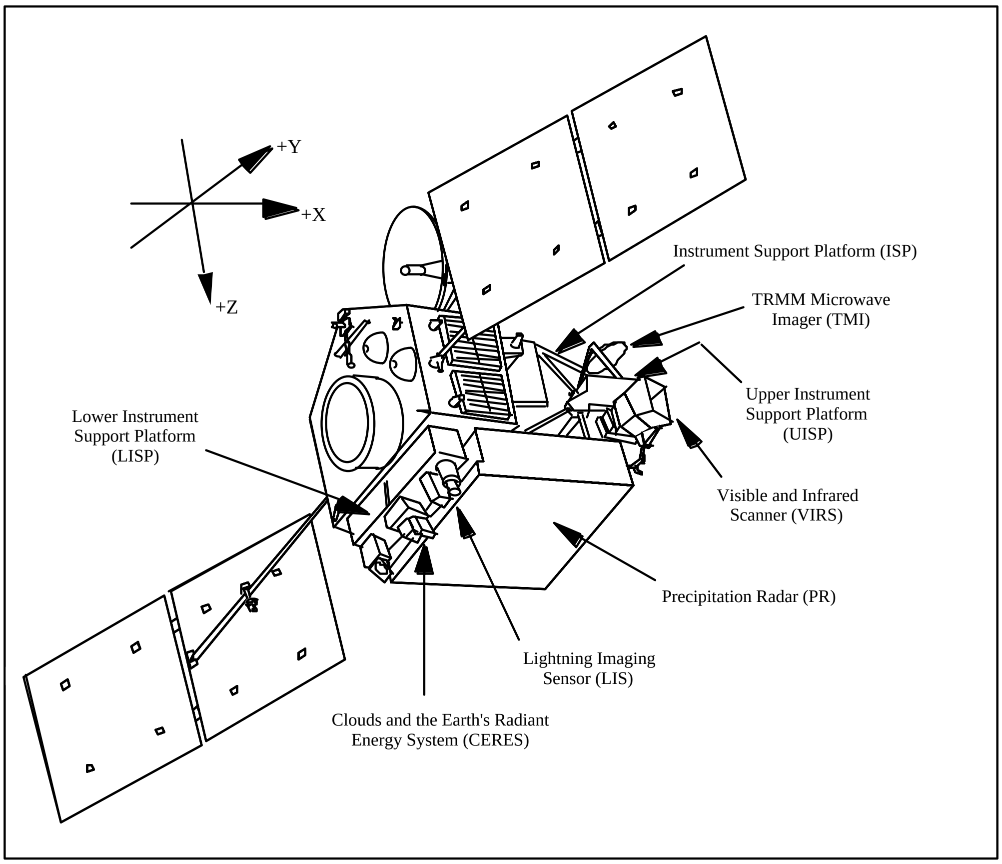


Figure 5-1 TRMM Instruments

5.1 Clouds and Earth's Radiant Energy System

The Clouds and Earth's Radiant Energy System (CERES) instrument has gathered excellent science data. Towards the end of 1998, instrument operations were hampered by a failing voltage converter. While only powered on for short periods in 1999, it has continued to gather comparison data for the science community and maintained most of the science objectives.

5.1.1 Operations

The FOT and LaRC Instrument Operations Team (IOT) have worked closely together in operating the instrument. The teams have planned and executed special operations and enhanced the mission planning software.

On 98-019, CERES began its nominal science operations of 2 days in Crosstrack mode and 1 day in Biaxial mode, with internal and solar calibrations performed nominally every other Wednesday.

The CERES instrument has been powered off twice (for spacecraft anomalies) in this report period (see Section 5.0 and Appendix F for more information). During the power on procedure on 98-115, the set solar cal angle and scan rate commands, setting elevation scanning to 6.6 seconds, were not accepted due to CERES being in the incorrect mode (Event #33). On 98-118, at 14:29 the Biaxial scan rate was corrected and at 14:32 the instrument was returned to normal science gathering operations. The solar cal angle was corrected when a solar calibration was performed on 98-118 at 16:32. The power on procedure was modified to verify the commands would be sent when in the correct mode.

CERES has been inadvertently placed in Safe mode three times. The first occurrence was on 98-101 at 00:00:04, due to a command in the stored load from the expanded Safing sequence (see the Mission Planning section and Event #25). Normal science operations were restored at 02:34. CERES was also placed in Safe mode while transitioning to Along-track operations during a Sun-avoidance region on 98-113 at 00:01:11 (see below and Event #30). Finally, Safe mode was commanded on 98-172 at 00:00:04, when a stored command load was not uplinked to the spacecraft and the Safing RTS executed (see the Real-time Activities section and Event #41). CERES was returned to science mode at 03:29.

CERES data has been lost twice due to recorder overflows on 98-160 and 98-172 (see Appendix F for exact times).

On 98-113, Along-track operations were included in the operational planning. This new operation combined a fixed azimuth position with solar-avoidance commanding at Beta angles between -20° and 20°. Along-track replaced every fifth Biaxial operation day. Table 5.1-1 lists the Along-track operational days and the days that solar-avoidance was commanded. Both LaRC IOT and the FOT made an extra effort to ensure the commanding was precise, since it began as a manually scheduled operation. The operations start-of-day commanding was incorrectly scheduled during a solar-avoidance zone, and the Sun Presence Sensor 1 sensed the Sun and placed CERES in Safe mode on 98-113 at 00:01:11. The recovery to normal science gathering placed CERES in Crosstrack mode at 01:57, then reconfigured back to Along-track at 02:50. A request was made to enhance the mission planning software to include the new operation and was installed on 98-216. The new mode could not be added to automated software, but rules were added to make semi-automated scheduling of commanding. The Along-track operation on 98-218 was the first to use the additional software rules to schedule commanding.

DOY	**Beta Angle Range**	**Sun-avoidance Commanding**
98-113	Beta < -20°	None
98-128	-20° < Beta < 20°	Yes
98-143	-20° < Beta < 20°	Yes
98-158	Beta > 20°	None
98-173	-20° < Beta < 20°	Yes
98-188	-20° < Beta < 20°	Yes
98-203	Beta > 20°	None
98-218	-20° < Beta < 20°	Yes
98-233	-20° < Beta < 20°	Yes

Table 5.1-1 CERES Along-track Operations Summary

A set of special internal calibrations were performed from 98-196 through 98-198. This test was conducted to cover eclipse periods and sunlight periods with full and abbreviated internal calibrations. Also studied during the calibration test were differences performed on Biaxial and Crosstrack operational days. Findings indicated that there were no major differences in data gathered and that full internal calibrations could remain scheduled during the nominal sunlight-only period that was previously used.

On 98-220 through 98-233, data was correlated with the Department of Energy's Atmospheric Radiation Measurement (ARM) site in Oklahoma. During Biaxial operational days, the instrument was commanded to Crosstrack mode during ARM fly-bys, then returned to Biaxial operations for the remainder of the GMT day.

A special micro-processor load, defining a new elevation scan was loaded to CERES on 98-240. The Noise 1 elevation scan mode, defined in the micro-processor load, was tested on 98-240 from 15:08 to 15:38 successfully. The new elevation profile was to be used in the 98-245 Deep Space Calibration. Due to the Data Acquisition Assembly (DAA) +15 V voltage converter anomaly, the instrument remained powered off during the maneuver.

5.1.2 DAA Voltage Converter Anomaly

The DAA +15V voltage converter began reaching the YH limit of 15.75 volts on 98-230 (Anomaly #69). Trending revealed that the converter began anomalous behavior of unregulation on 98-212. See Figure 5.1-1 for the daily maximum and minimum voltage of the converter. The converter began with nominal regulation on Crosstrack operational days, while hitting YH limits during Biaxial and Along-track operational days. Also a diurnal temperature effect was seen during the middle of the GMT day that coincided with the daily maximum voltage. On 98-237, CERES was placed in Crosstrack mode only to reduce the motor bearing temperature and converter voltage. On 98-244, the instrument was powered off at LaRC's instructions, when the converter reached a high value of 16.5 volts.

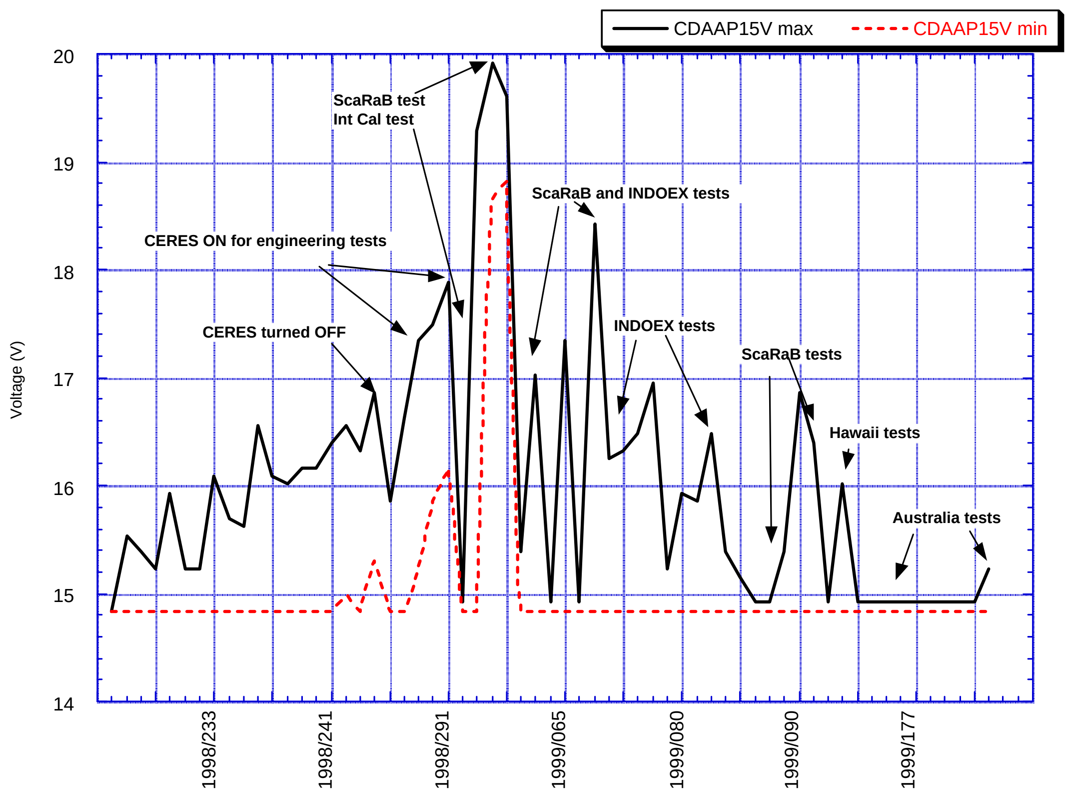


Figure 5.1-1 CERES DAA +15 V Converter Daily Voltage

On 98-287 at 00:56, CERES was powered on to exercise several operations to characterize the behavior of the converter and gather more engineering data. Figure 5.1-2 shows how the converter voltage stops regulating as the motor bearing reaches a certain temperature. Figure 5.1-3 shows the degradation of the temperature threshold of the converter. TSMs #35 - 37 and RTS #34 were built and loaded on 98-260 to the spacecraft to monitor the converter and power the instrument OFF if the DAA voltage exceeded 18.0 volts. On 98-291 at 09:56, TSMs #35 - 37 exceeded limits and RTS #34 executed and powered off the instrument. Along with the engineering test, a life test was started at Langley to determine the operability of the electronics that are supplied by the anomalous converter. The electronic components were tested with 30 volts supply without any degradation in performance to date.

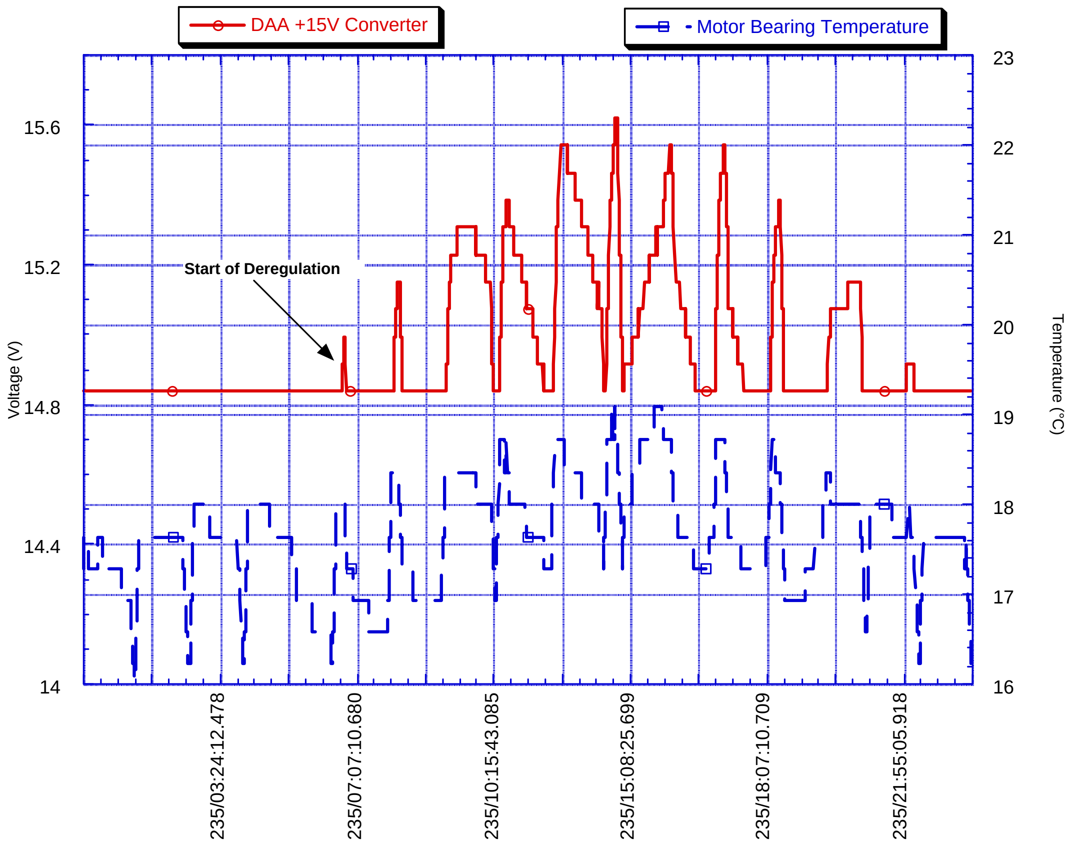


Figure 5.1-2 +15 V DAA Converter and Motor Bearing Temperature

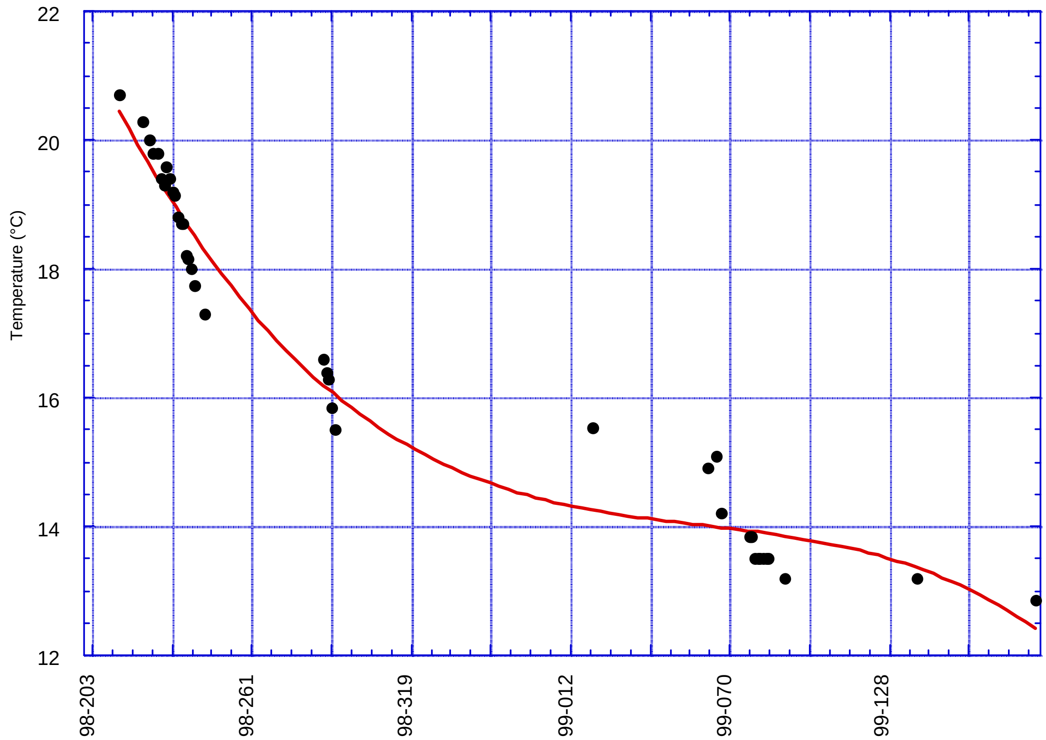


Figure 5.1-3 Motor Bearing Temp Threshold where Unregulation Begins

CERES remained off for the remainder of 1998, while the Langley Tiger Team assessed the behavior and cause of the voltage converter anomaly. The voltage converter starts going out of regulation at a temperature that can be assessed using the motor bearing telemetry. The temperature limit for regulation decreases with time and use of the instrument. The results from the engineering test confirmed that the converter's degradation behavior was well understood and that it did not affect the science or calibration data gathered. The conclusion was that there was enough regulation life in the converter to operate for important field tests and eventually power on permanently after the Terra launch.

5.1.3 Operations with the Anomaly

In the first half of 1999, the instrument was powered on for operational use and science collection, in coordination with various ground sites and instruments. Special micro-processor loads were retrieved and uplinked to the instrument during power on for special internal calibration operations (INTSEQ11 and INTSEQ12). Table 5.1-2 illustrates the sites and dates of operations. During the January 1999 test with the Scanner for Radiation Budget (ScaRaB) mission, a series of specially defined internal calibrations were commanded. The calibrations were scheduled after the converter began the anomalous regulation. The findings confirmed the theory that calibration data was not affected by the increase in temperature or voltage.

GMT	SITE	Activities
99-019/21:14 to 022/02:47	ScaRaB Instrument	INTSEQ11, CT at 243.66°
99-062/03:03 to 068/21:52	ScaRaB/ INDOEX	INTSEQ12, Solar Cal, CT at 243.66° and 180°
99-076/05:36 to 085/10:33	INDOEX ground tests	A to B ASYNC, CT at 180°
99-088/23:08 to 091/05:15	ScaRaB Instrument	Crosstrack (CT) at 180°
99-137/18:39 to 138/02:50	Hawaii ground tests	Solar Cal, INTSEQ12
99-170/02:02 to 180/23:30	Australia ground tests	CT at 180°
99-181/19:25 to 186/21:00	Australia ground tests	CT, SWICS test, Int Cal, Gimbal data

Table 5.1-2 CERES Activities in 1999

The LaRC team operated the instrument with some restrictions based on the findings during the engineering tests. The instrument would not be powered on if the Instrument Power Switching and Distribution Unit (IPSDU) Thermistor Monitoring Module (TMM) reading for the motor bearing temperature was above 10.5 °C. The instrument would not be powered off if the converter voltage reading reached 19.56 volts (the telemetry saturation point), but would be powered off immediately if the voltage was above 18.6 volts (but below the saturation value) in real-time. Once the saturation value is met, it would be difficult to determine the time at which the converter was no longer regulating.

The IOT requested that CERES be excluded from spacecraft contingency load-shed. This request came after it was observed during the life test that when the voltage converter is completely degraded, and the input voltage is removed and later restored, a permanent failure mechanism exists in the voltage converter secondary due to current inrush. After careful review the FOT, FSW, and GSFC AETD engineering group recommended that CERES remain powered on for ACS contingencies, but would still be powered off for Low Power. A series of telemetry monitors will be used to monitor the total current and power the instrument off in the event that an electrical short is detected. The FSW group will have the new monitors built before the Terra launch at the end of 1999.

Once the ground site tests have been finished, CERES will be powered on after the Terra mission is launched in late 1999. It will be powered on permanently to coordinate science data with the Terra CERES instruments, regardless of its status in the contingency load-shed scenario.

5.1.4 Trending

All temperatures and voltages, with the exception of the DAA +15V converter, have been as expected and within limits. Most of the temperatures vary with Beta angle, such as the Power Converter Assembly (PCA) Radiator temperature that varies between 22.9 °C and 29.9 °C, with the lower temperatures at Beta 0° (see Figure 5.1-4). The azimuth gimbal upper bearing temperature ranges from 19.45 °C to 27.6 °C at Beta angles greater than 50° and 16.92 °C to 23.7 °C close to Beta 0° (see Figure 5.1-5). The IPSDU total CERES current (the IPSDU-A current multiplied by two), shown in Figure 5.1-6, reached highs of 2.4 amps. The current ranges from 2.1 to 2.4 amps during Biaxial mode operations and ranges from 1.7 to 1.8 amps during Crosstrack mode. The currents are higher near Beta 0°.

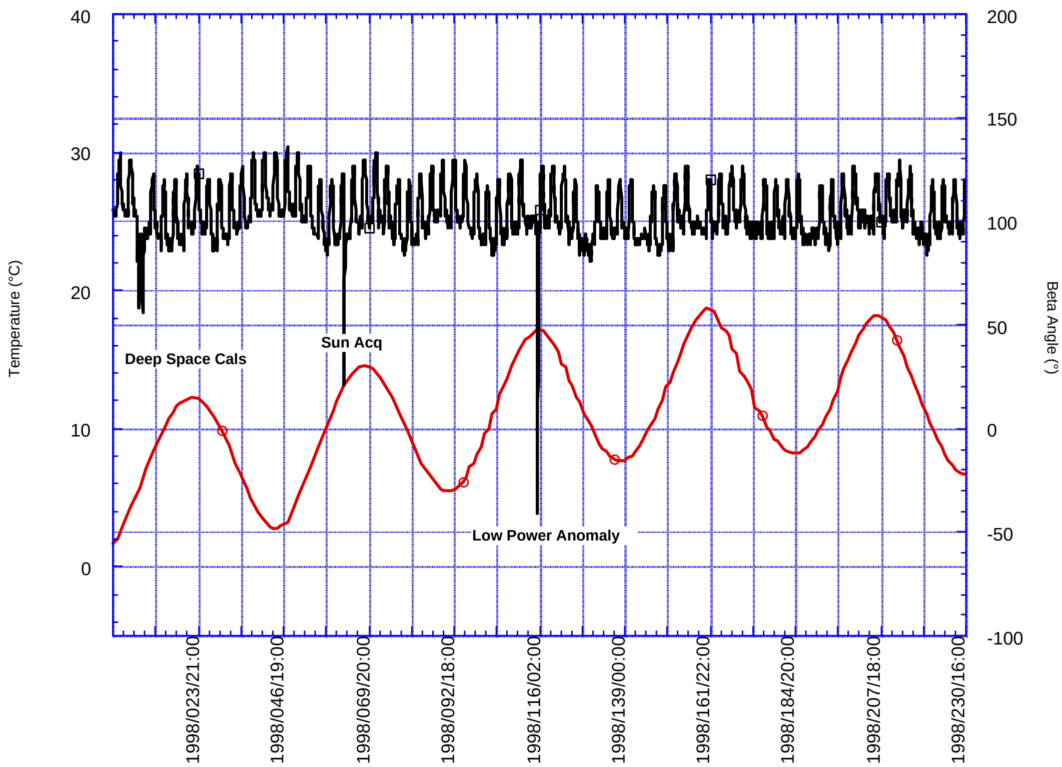


Figure 5.1-4 PCA Radiator Temperature and Beta Angle

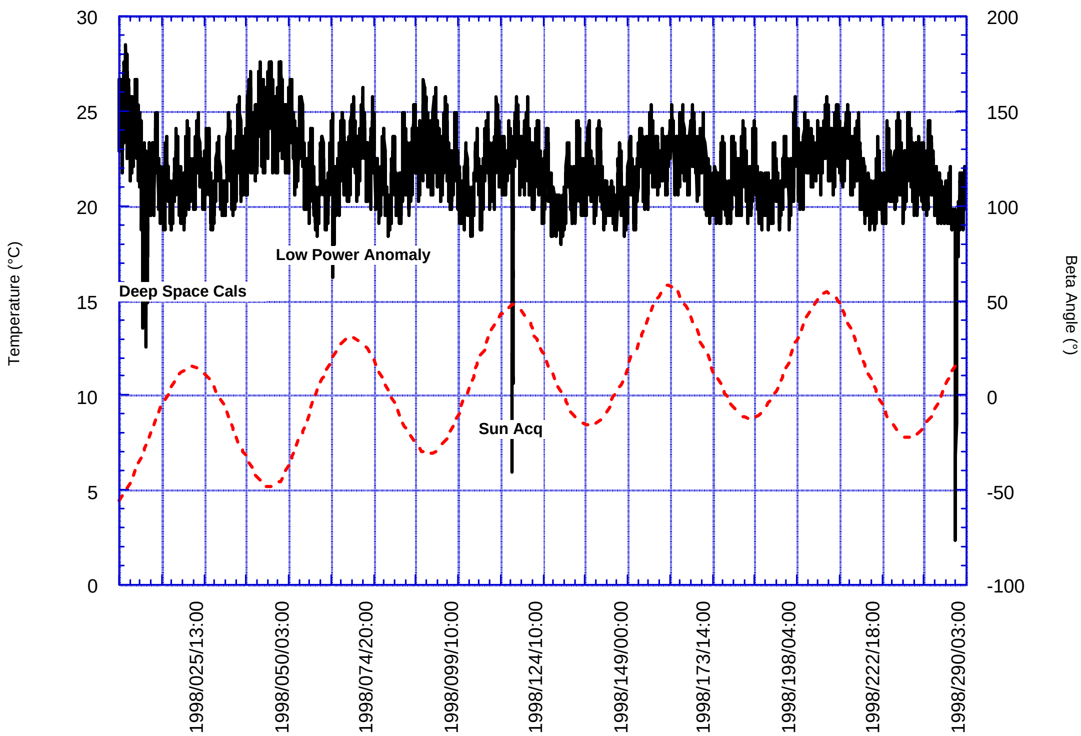


Figure 5.1-5 Azimuth Gimbal Upper Bearing Temperature and Beta Angle

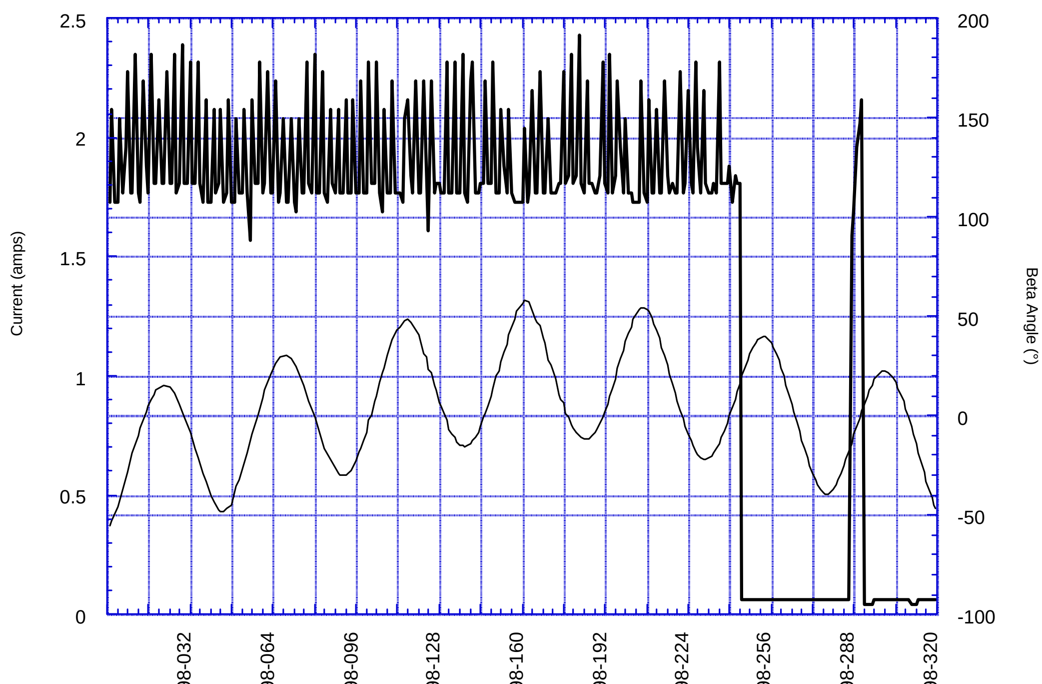


Figure 5.1-6 CERES Total Current and Beta Angle

Interested parties may view CERES information and quick-look results, including Top-Of-Atmosphere flux estimates and geolocation plots at the following LaRC CERES web site:

http://asd-www.larc.nasa.gov/ceres/trmm/ceres_trmm.html

5.2 Lightning Imaging Sensor

The Lightning Imaging Sensor (LIS) instrument has operated nominally in the 18 months of science operations. The instrument has collected excellent science data for the MSFC, which has distributed over 1 Tb of data to 50 users in 10 countries.

5.2.1 Operations

Throughout the 18 months, LIS has operated in the 8 kbps background send on mode. This was a change from the default 6 kbps rate in order to record more background data.

Since changing to the 8 kbps background mode, LIS has experienced packet sequence errors even though the maximum number of packets are received each day. The instrument occasionally has a science data packet ready before the data bus is ready to receive it (at one second intervals) causing a packet to be missed. Approximately once a month, MSFC requests a sequence of commands to reset the instrument, reconfigure to the 8 kbps background mode, and reload the thresholds (see Figure 5.2-1) to reduce the number of packet sequence errors.

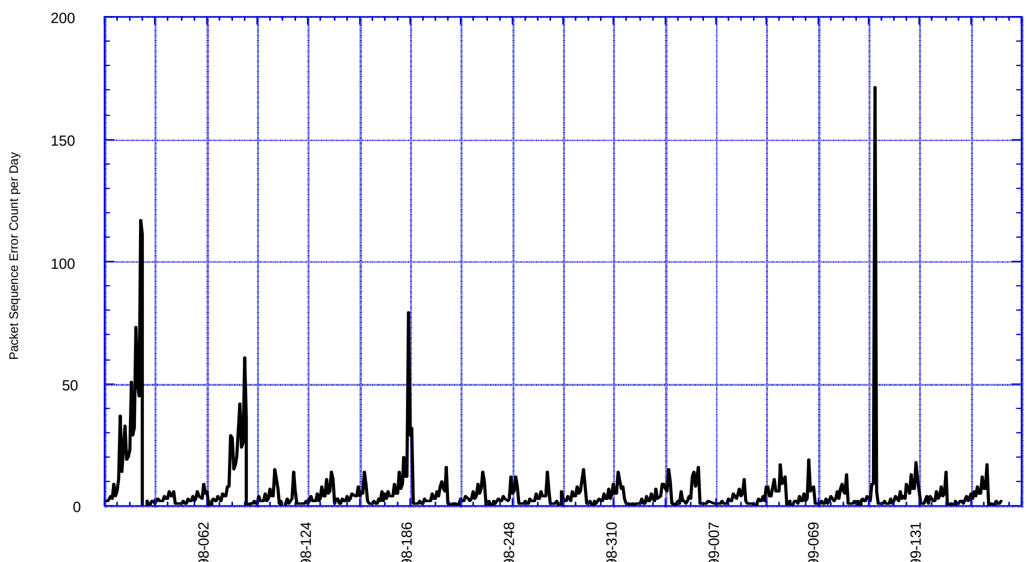


Figure 5.2-1 Number of LIS Packet Sequence Errors per Day

In an effort to maximize science data from LIS, and reduce the number of false events recorded, the threshold settings were re-adjusted several times during the instrument checkout phase. On 98-041 at 16:56, the final threshold adjustment was made and the values are shown in Table 5.2-1.

Threshold	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Setting	16	16	18	18	18	18	18	20	20	20	20	20	22	63	63	63

Table 5.2-1 Nominal LIS Threshold Settings

The instrument has been powered OFF four times in the report period (see the introduction to the instrument sections for more information). In all instances, LIS was safely powered back ON and resumed collecting science without incident.

There have been three times that LIS has lost data, due to recorder overflows on 98-112, 98-160, and 98-172 (see Appendix F for exact times).

5.2.2 Trending

Long term trending of LIS temperature and electrical parameters have shown no deviations or potential problems.

For more information on the instrument science data, reference the LIS websites at *http://thunder.msfc.nasa.gov/LIS/* and *http://ghrc.msfc.nasa.gov/*.

5.3 Precipitation Radar

Checkout activities ended on 98-033, and since then, the Precipitation Radar (PR) has operated nominally, producing excellent science data.

5.3.1 Operations

After each power-up recovery following anomalies and special events (see Appendix F), a NASDA scheduled Internal calibration was performed to verify the nominal status of the Frequency Conversion/IF (FCIF). While being left on during the anomaly on 99-003 for ~3 hours, there were no reports of other spacecraft being affected by PR's radar.

There have been several times where science data has been lost for reasons other than a spacecraft anomaly. The days where data was lost, due to a virtual recorder overflow, are 98-116, 98-160, and 98-172. Other days of lost data, not due to a recorder overflow, are

98-062, 98-063, 98-065, and 98-115. The lost data on 98-065 (Anomaly #61) can be attributed to a bandwidth problem due to spacecraft dwell and PSIB B being on simultaneously. For exact times and reasons for the lost science data, refer to the Appendix F.

TMI scientists have reported interference seen in the data (refer to the TMI section). On 98-245, a Deep Space Calibration was scheduled to help troubleshoot the cause. Normally, PR is placed in Standby mode for the duration of the calibration, but one theory for the TMI problem was that PR radiation was affecting the science data. To test the theory, PR would have to radiate out into space. After working with FDF to avoid radiating towards other spacecraft, a suitable time was selected. At 11:23:41, PR was placed in Standby mode and then set to radiate (Observation mode) at 12:18:00 for a duration of one minute. It was then returned to normal science collection mode 30 seconds after the maneuver completion at 13:06:38.

In order to enhance the receiving level, NASDA decided to change the receiving gain control attenuator from 6dB (power up default) to 9dB. The instrument has been operating at the 9dB level since 98-033 at 23:30 with no problems.

During the timespan of the report, there have been 22 PR External calibrations requested by NASDA. These calibrations are listed in Table 5.3-1. With the exception of two command requests, all External calibrations were carried out successfully (Event #102).

At the time of Launch, there were two regions defined where PR could not radiate due to interference issues as outlined in the International Telecommunications Union (ITU) Radio Regulations. The instrument was placed in Standby mode over WSC and a tracking station in Australia. On 98-009, it was decided that placing PR in a non-radiating mode could be eliminated over WSC. On 98-168, the EOC decided to use Internal calibration mode over Australia instead of Standby mode. Internal calibration mode is also a non-radiating mode, but is also used to help interpolate External calibration data.

In addition to placing PR in Internal calibration mode over Australia, an Internal Calibration was performed every Wednesday at 03:00, for a duration of one minute. On 98-238, NASDA decided that the Australia region Internal calibrations met their requirements and that the weekly Wednesday calibrations were no longer needed.

There have been two times when PR has radiated over Australia. The first one occurred when outdated FDF products, without Delta-V data modeled, were used for scheduling on 98-013. The scheduled times were 11:14:03-11:15:17, and the actual times were 11:14:39-11:15:53. To avoid this, the age of Predicted Site Acquisition Table (PSAT) files was restricted when building loads. Also, a larger area was defined by placing PR in a non-radiating mode 30 seconds (originally 20) before the predicted region and returning to Observation mode 30 (originally 20) seconds after the predicted region. The other time

PR radiated over Australia occurred on 98-172 at 01:38:59-01:40:10, when the daily ATS load was not uplinked in time to include this region (Event #41).

Beam #	Time of External Calibration
16	98-044-02:49:44
83	98-044-04:26:09
56	98-093-01:47:35
27	98-093-03:24:02
29	98-142-23:33:11
55	98-143-01:09:37
62	98-283-22:53:35
17	98-284-00:30:00
68	98-284-23:17:19
56	98-342-16:12:34
67	98-342-17:49:00
30	98-343-16:36:18
63	99-040-07:57:47
14	99-040-09:34:13
66	99-041-08:21:47
45	99-130-09:10:43 missed cal
82	99-130-10:47:10 missed cal
35	99-131-09:34:39
36	99-132-08:21:58 replacement cal
58	99-166-14:11:56
65	99-166-15:48:22
30	99-167-14:35:38

Table 5.3-1 External Calibrations (PREXTCALA)

On 98-306, the Australia region restriction was removed and would only be required for certain times (a few times a year) by the Australia tracking station. Since this took away Internal calibration data, NASDA and the FOT devised a new scenario. A weekly Wednesday Internal calibration would be scheduled at the first occurrence of -35° Latitude, for a duration of one minute. This latitude was chosen because PR receives less useful data over this region of ocean. The new scenario was implemented on 98-308.

The Australia region restriction was put back in effect on 98-365 and has been in place through June 99. The Wednesday Internal calibrations were again removed from operations.

On 98-031 at 03:00, PR was placed in Health Check mode for one minute and thirteen seconds to check the status of RAM/ROM for the System Control Data Processing unit

(SCDP). PR was placed in Analysis mode on 98-224 at 03:45 to collect data for the Low Noise Amplifiers (LNAs).

Instrument Operations Procedure (IOP) #525 states that the K1 relay for the PR survival heater will be opened prior to turn on to avoid overheating the instrument. It was found in Integration & Test (I&T) that the heater would stay on past the set-point due to a temperature gradient. This gradient is present during power on. Therefore, to avoid damaging PR, the relay would remain opened for 48 hours after turn on. Due to confusing restrictions on when to actually perform this operation, NASDA decided, after the Leonid Storm, that IOP-525 will be done before all power-on activities.

5.3.2 Issues and Concerns

There is the possibility that the PR survival heater relays will be opened in nominal mission mode and will remain open to help ensure a power positive state in Sun Acquisition mode or Safehold if the -Y solar array drive fails. Research has found that the Qualifying Temperature of the PR components in a non-operating mode is -30 °C. The instrument has already experienced temperatures of approximately -22 °C in Sun Acquisition, which is also the turn-on set point of the -Y and center panel PR survival heaters. The plan would be to close the survival heater relays if the Observatory is in a power positive state while in Sun Acquisition mode or Safehold. Plans might also include pitching the Observatory to warm PR while in an emergency mode. This issue will be discussed thoroughly by the MD, Principal Investigator (PI), FOT, AETD, and NASDA representatives before any implementation steps are taken.

At the World Radio Conference in 1992, a primary Fixed Satellite Service (FSS) allocation was added in the 13.75-14.06 GHz band, and PR was protected through January 1, 2000. During January 1, 2000 to January 1, 2001, all FSS operators are allowed to operate in this band, but as a secondary user. After January 1, 2001, there will be no requirement or obligation for FSS uplinks to protect TRMM operations. The FOT is closely monitoring this situation to see what new restrictions would be placed on the operation of the instrument. FDF has an agreement with the Palapa Ground Stations to provide TRMM flyover times, as soon as the stations become operational. The ground controllers will avoid any commanding for a one minute duration during these flyover times.

5.3.3 Trending

All PR temperatures and currents have remained within limits, even during planned events like the Deep Space Calibrations and the Leonid Storm and anomalies like Low Power and Sun Acquisition. As shown in Figures 5.3-1 through 5.3-3, the panel temperatures have fluctuated with the Beta angle. The peaks for the FCIF have corresponded to a Beta angle of ±58°, while the peaks for the SCDP and Power Supply have corresponded to a Beta angle ± 30. The lows for all three temperatures have corresponded to a Beta angle of 0° because the spacecraft body insulates PR from the Sun when it is overhead. The maximums for the FCIF, SCDP, and Power Supply panel temperatures are 9-12 °C, 17-18 °C, and 7-9 °C, respectively. The minimum temperatures are not displayed on the figures but are within a couple of degrees of the maximums for all three panel temperatures. The coldest that all three temperatures have been was during the GSACE/Sun Acquisition anomaly on 99-003, due to the length of time that the instrument was powered off. These temperatures were -23 °C (FCIF), -19 °C (SCDP), and -17 °C (Power Supply) and approximately correspond to the thermostat close setpoint for each of the three heaters.

All other temperatures have displayed similar behaviors.

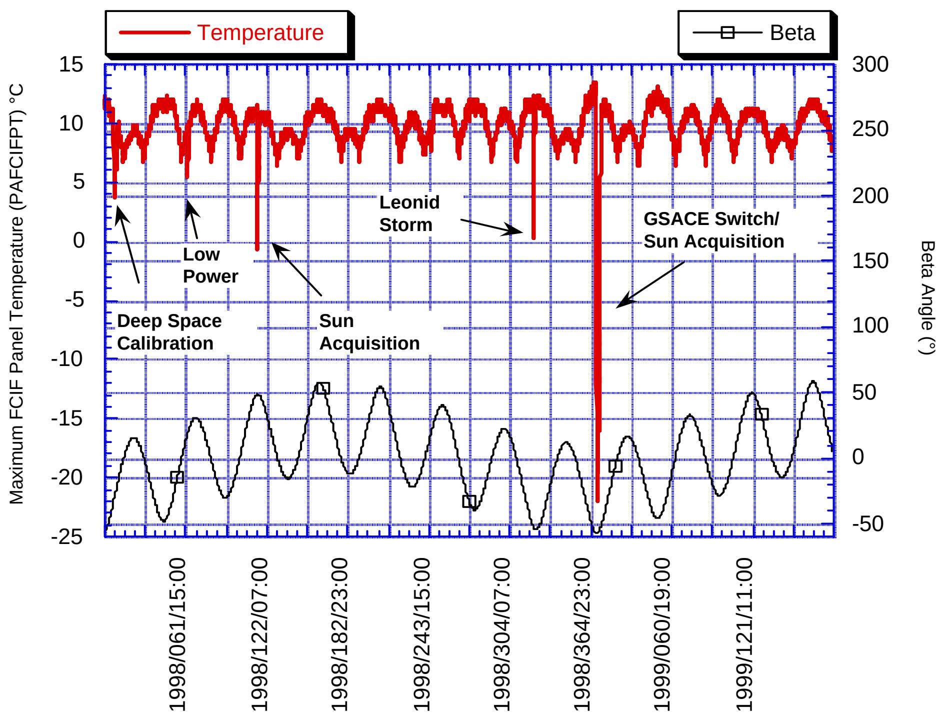


Figure 5.3-1 FCIF Panel Temperature and Beta Angle

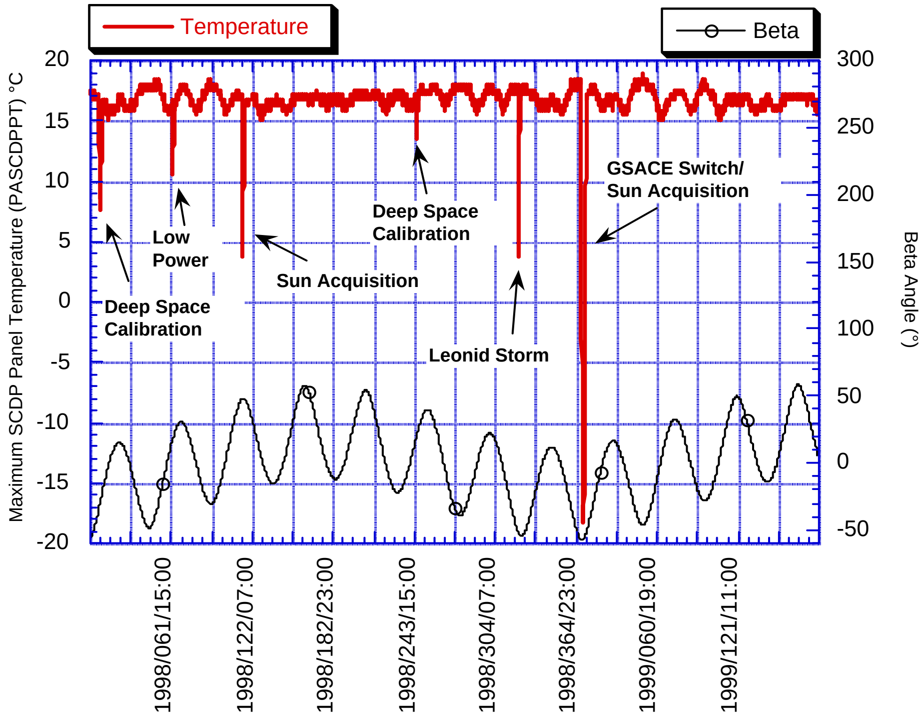


Figure 5.3-2 SCDP Panel Temperature and Beta Angle

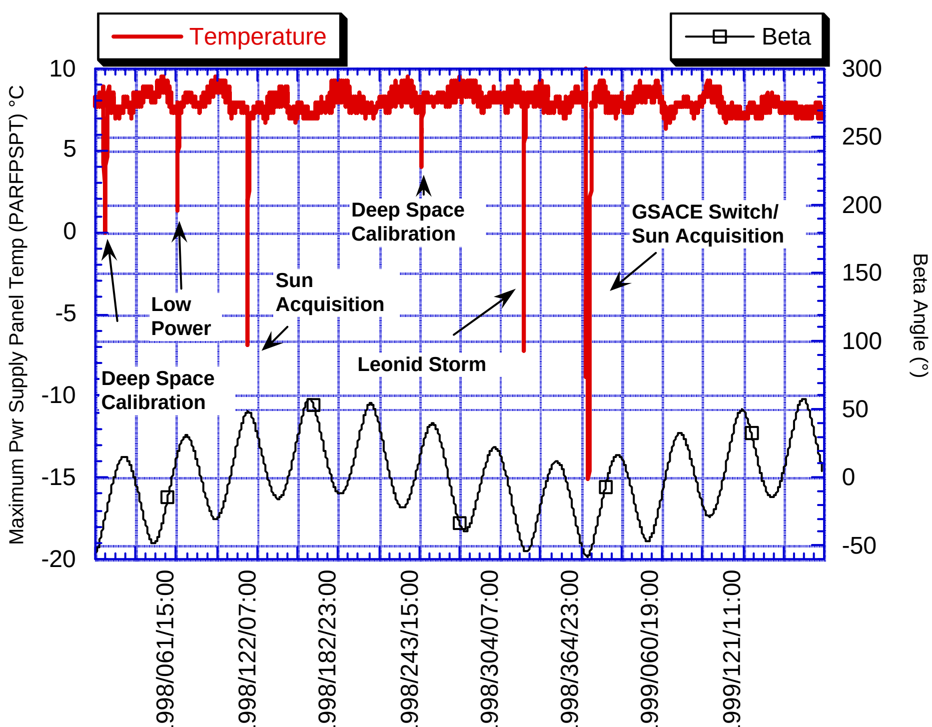


Figure 5.3-3 Power Supply Panel Temperature and Beta Angle

5.4 TRMM Microwave Imager

The TRMM Microwave Imager (TMI) instrument has performed nominally and provided excellent science data during the timeframe of January 1998 through June 1999. The Bearing and Power Transfer Assembly (BAPTA) has shown no signs of degradation.

5.4.1 Operations

On three occasions, TMI has lost science data due to a recorder overflow: 98-026, 98-160, and 98-172.

Software Bus (SB) errors, resulting from the known "timing conflict" within the TMI instrument, continue to occur (Anomaly #40). Software bus send errors were detected on 98-014, 98-067, 98-090, 98-185, 98-277, 98-289, 98-321, 98-331, 98-355, 99-026, and 99-180. When this happens, TMI does not output any data for two scans, which was seen in both the science packet sequence count and by the FDS Payload Manager (PM). This problem occurs approximately once every 49 days, which is better than the predicted rate of once every 18.4 days.

The TMI science team has noticed an interference source in science data due to a warm source, or possibly PR radiation bleeding into the feedhorns. A Deep Space Calibration (inertially fixed mode) was done on 98-245, for one orbit, to determine the source of interference and to verify that the offset was consistent with earlier levels. PR was allowed to radiate into deep space to see if it was indeed the source of interference for TMI (see the PR section for exact times). It was concluded that PR was not the source. This interference is currently being masked out in ground processing. Currently there are no other calibrations planned, due to the risk of causing a thermal short in VIRS (see the VIRS section).

5.4.2 Trending

The instrument current has remained well within limits (YH is 2.8 amps). As shown in Figure 5.4-1, the IPSDU total TMI current (the IPSDU-A current multiplied by two) reached highs of 2.5 amps. The current draw reaches its highest level around a Beta angle of 0°±18°, which corresponds to the BAPTA heater turning on and off. The setpoints of the BAPTA heater are 3 °C ON and 9 °C OFF.

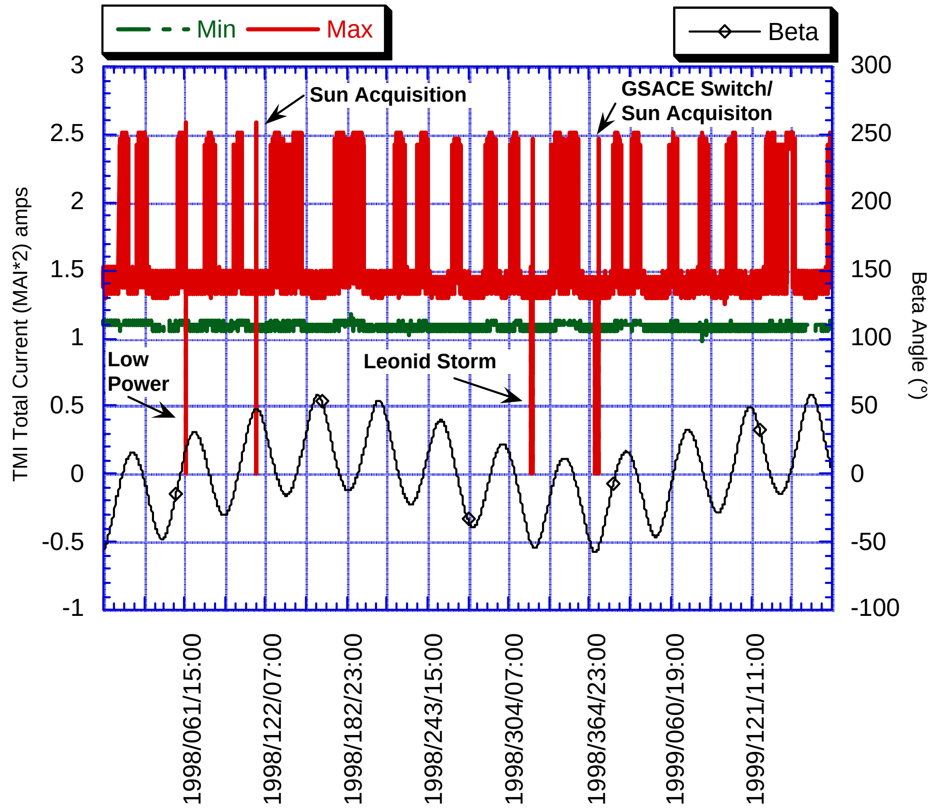


Figure 5.4-1 TMI Current and Beta Angle

The baseplate temperature has stayed within limits during the two extreme Beta angles of +58° and -58°. It peaks at a Beta angle of ±35° and hits lows at Beta angle 0° (see Figure 5.4-2). The temperature peak occurs at Beta ±35° instead of the two extremes because of the way the Sun heats TMI (more directly instead of edge-on). The temperature reached its highest point during the Deep Space Calibration in January. Temperatures also display higher values in the negative Beta range, which is due to the direction of flight; TMI in back or front.

All other TMI temperatures have displayed similar behavior.

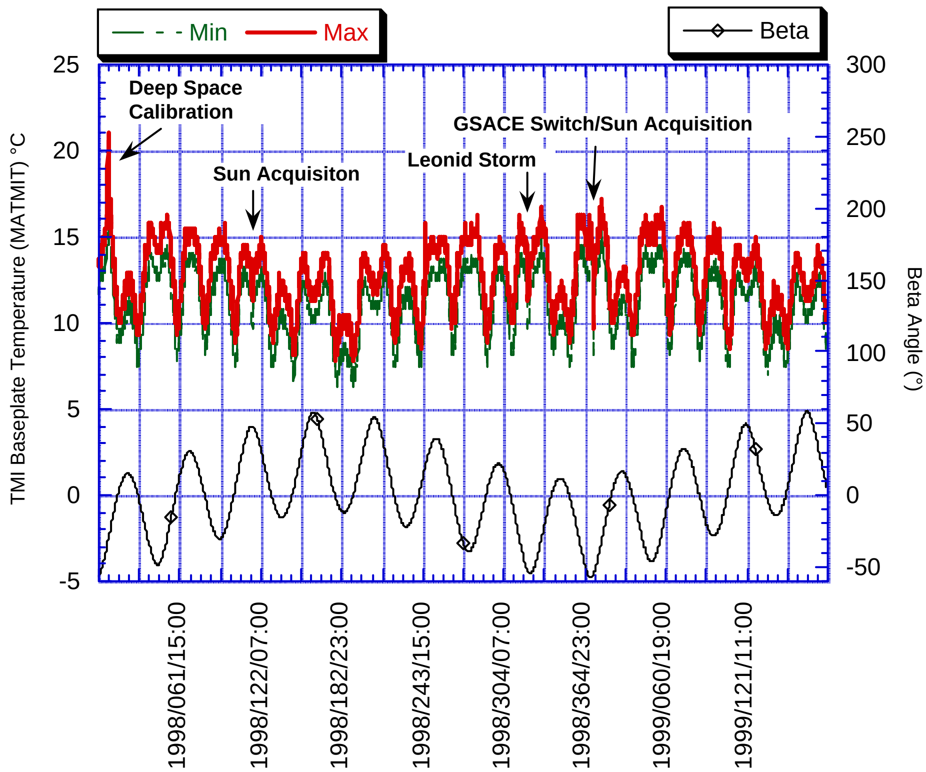


Figure 5.4-2 TMI Baseplate Temperature and Beta Angle

For information on the TMI data products, including images, go to the TMI web site at http://www.ssmi.com/tmidata.html.

5.5 Visible and InfraRed Scanner

The Visible and InfraRed Scanner (VIRS), built by Hughes at Santa Barbara, has gathered excellent science data and has operated as expected. The VIRS science data has been very useful to other TRMM instrument scientists: the data collected is used in coordinating analysis with the data collected by their instruments.

5.5.1 Operations

The housekeeping data shows that all parameters (currents, voltages, and temperatures) are within expected ranges. The scanner module blackbody temperatures are maintained within the 0 °C to 20 °C calibration range by using the 8.5 W and 15 W heaters (see Figure 5.5-1). The heaters are operated through ground commands. The ground system configuration monitor (Configmon) generates messages when the heaters are approaching their set limits. Although the power supply temperature is within limits, it has operated up to 42 °C (YH limit is 45 °C), as shown in Figure 5.5-2. The power supply temperature can be reduced when necessary, by reducing the use of the 15 W heater.

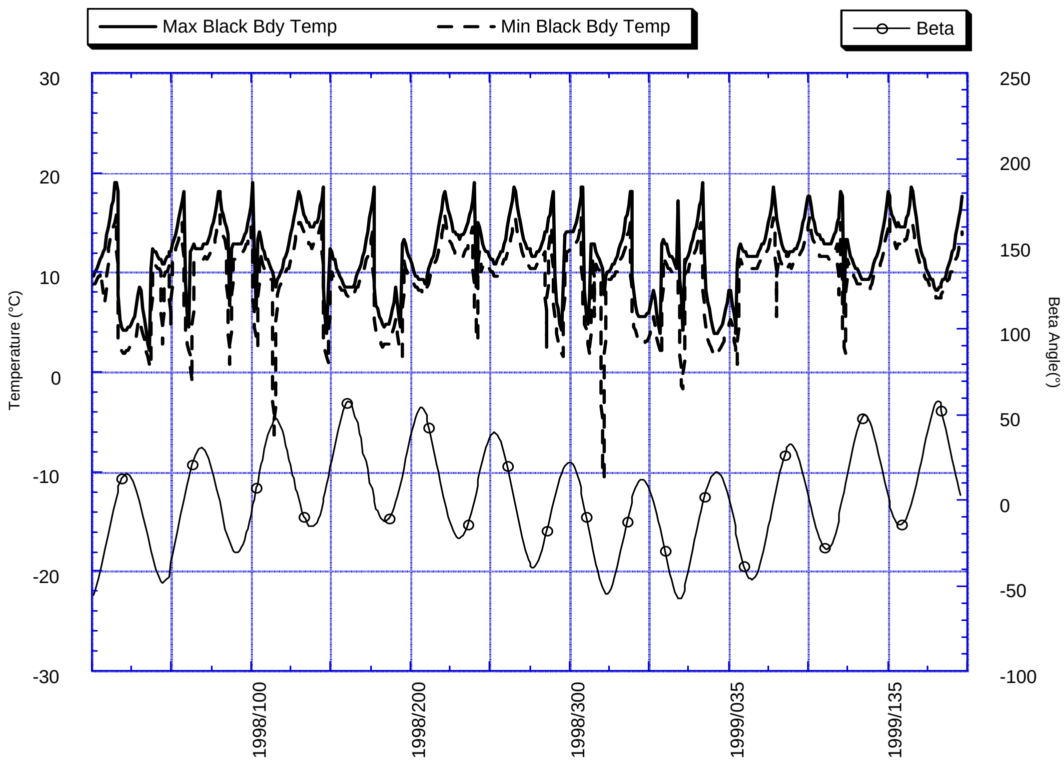


Figure 5.5-1 VIRS Blackbody Temperature and Beta Angle

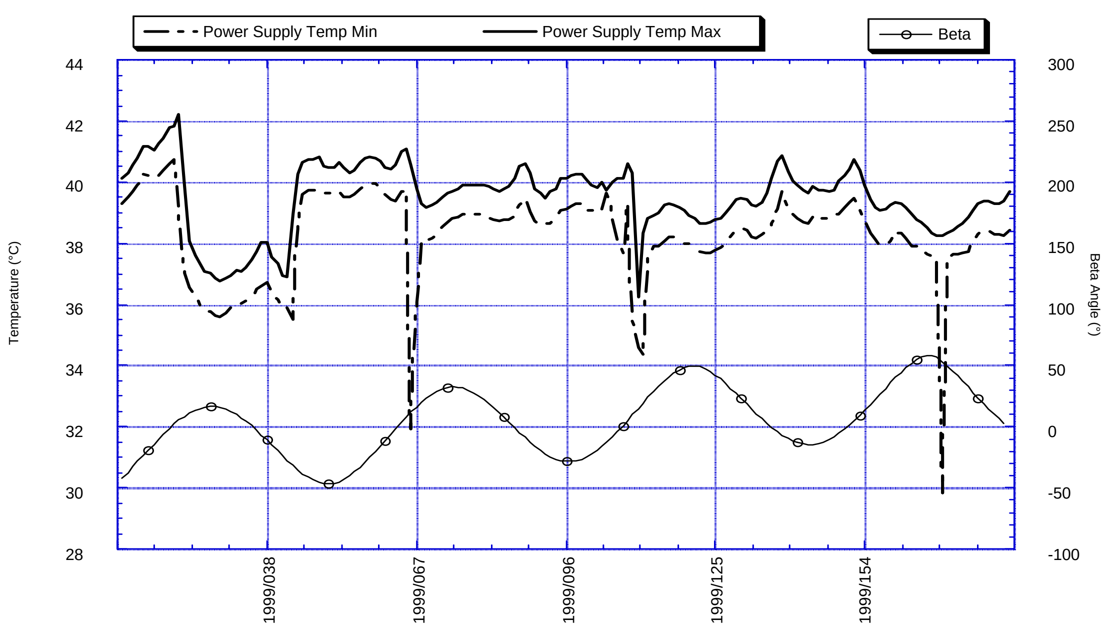


Figure 5.5-2 VIRS Power Supply Temperature and Beta Angle

The instrument has been powered off four times, due to Low Power, Sun Acquisition, Leonid Storm, and GSACE Switch/Sun Acquisition. VIRS science data has been lost on a few occasions - see the introduction to the instrument sections and Appendix F for specific times and dates.

Event message flags (hex 2F, 20, 30, 78) are regularly received from VIRS in telemetry. The following is a description of the event messages:

Event Message	Description	Notes
2F	The 1773 received two transmit subaddress reads without having received an acknowledge subaddress read first.	Subaddress 25 read twice without subaddress 29 read.
20	The indexes for the housekeeping data buffer were at an unexpected value.	The housekeeping data assembly buffer or the transmit buffer offset were not at 0 or 64.
30	The 1773 received three transmit subaddress reads without having received an acknowledge subaddress read first.	Subaddress 25 read three times without subaddress 29 read.
78	The 1773 interface circuit has held an interrupt request signal active for an extend period.	The 1773 has held the standard interrupt signal high for more than 100 times through the background process so a rest is needed.

Table 5.5-1 VIRS Event Message (in Hex) Description

These warning messages had been seen before Launch and do not indicate any problem with the instrument, although some of them do coincide with spacecraft bus errors (see FDS section).

The solar calibration requests, which are received about twice per month from the instrument scientist through TSDIS, are normally incorporated into the regular spacecraft daily loads for uplink and execution. The GSOC mission planning software was adjusted to help predict more accurately the solar and lunar interference with the solar port by updating the port angles. The solar calibrations performed on 98-174, 175, and 176 were the first to use the new GSOC template. More accurate solar calibration data has been gathered since its adjustment and the new template is being used to this date. The VIRS planning aids are still not optimized completely and efforts are currently under way to make them more accurate.

5.5.2 Day/Night Mode

VIRS transitioned between Day and Night modes to conserve data storage space. Day mode uses all five channels during sunlight periods, while night mode uses only three during eclipse periods. On 98-051 during orbit #1338, VIRS was placed in Day mode for one orbit and remained in that mode through the eclipse period of 18:41 to 20:13. After analyzing the data from this orbit, it was noticed that Channels 1 and 2 could detect thermal leaks while in eclipse. This could be used for better calibration of the science data, and could also be used by some of the other instruments for data comparison. On 98-097, TSM #29 and RTS #33 were disabled and VIRS was placed in Day mode permanently. The virtual recorders in the DS Quota Table (S/C #73) were adjusted to accommodate the larger amount of data being recorded (see FDS section for more information).

5.5.3 Deep Space Calibration

Inertially fixed CERES Deep Space Calibration maneuvers were performed on 98-007, 008, and for one orbit on 98-245. Excellent VIRS data was obtained from the cold space scene viewed through the aperture during the first part of the first inertial orbit on each day. Due to spacecraft orientation, the Earth Shield Door did not block the Earth heat input to the Cooler during these orbits. The Cooler, therefore, warmed up above the temperature range for valid science data collection. The Cold Stage temperature climbed to approximately 160 K, and while the Intermediate Stage temperature reached 185 K, the mounting ring recorded a temperature of -24 °C. Outgas telemetry mode was enabled when the Cold Stage temperature reached 133 K in order to receive a valid temperature reading. After the maneuvers, the Cooler did not return to its minimum temperature of 107 K, but settled between 111.4 K (at Beta angle close to ±48°) and 115.4 K (at a Beta angle of 0°). It was decided that the Cold Stage temperature was still within specification limits and providing excellent science, so no action would be taken to restore the pre-maneuver temperature unless it further degraded, or the opportunity presented itself.

On 98-115, the first opportunity to restore the Cold Stage temperature occurred, after the instrument was powered off due to the Sun Acquisition Anomaly (Anomaly #67). Two other successful outgassing procedures have been performed since then - in November 1998 and January 1999. All three outgassing operations went extremely well. After the Cooler returned to the 107 K operating temperature, VIRS was returned to normal operations, see Table 5.5-2 for outgassing times.

Event	Outgas Start	Return to Nominal
ACS Sun Acq	98-115/12:32:02	98-116/21:03:58

Post Leonid	98-322/01:33:33	98-322/22:38:39
GSACE Sun Acq	99-005/23:48:40	99-007/17:19:27

Table 5.5-2 VIRS Outgassing Operations

5.5.4 WatchDog Self-Reset

VIRS has performed 8 self-resets since Launch (Anomaly #56). Table 5.5-3 shows the VIRS reset times. A reset was documented during ground testing and was thought to be associated with warning message #20. However, this cannot be confirmed for all cases, since the VIRS event buffer is cleared on reset and the events are received on a 10 second packet. The instrument must be reconfigured back to normal science gathering mode when a reset occurs. A TSTOL procedure and a LOP have been developed to restore the instrument to normal operations in a timely manner.

Self-Resets	Configured to Nominal
98-044/12:49:10	98-044/14:06:49
98-050/06:07:15	98-050/07:10:32
98-086/20:01:42	98-086/20:17:44
98-286/00:38:30	98-286/03:13:38
98-316/12:01:30	98-316/12:58:05
99-065/03:07:52	99-065/05:24:35
99-065/22:13:10	99-065/22:24:45
99-104/22:45:36	99-105/00:40:07

Table 5.5-3 VIRS Reset Times

5.5.5 Trending

Many housekeeping mnemonics are trended on a weekly basis. The Cold Stage temperature varies by approximately 7 K depending on the Beta angle. A variation of 0.5 K is also seen between orbital eclipse and daylight (see Figure 5.5-3). The Intermediate Stage temperature has also been found to be Beta angle dependent, and the temperatures vary between 160 K at Beta 0° and 154 K at Beta angles above/below ±15° (see Figure 5.5-4).

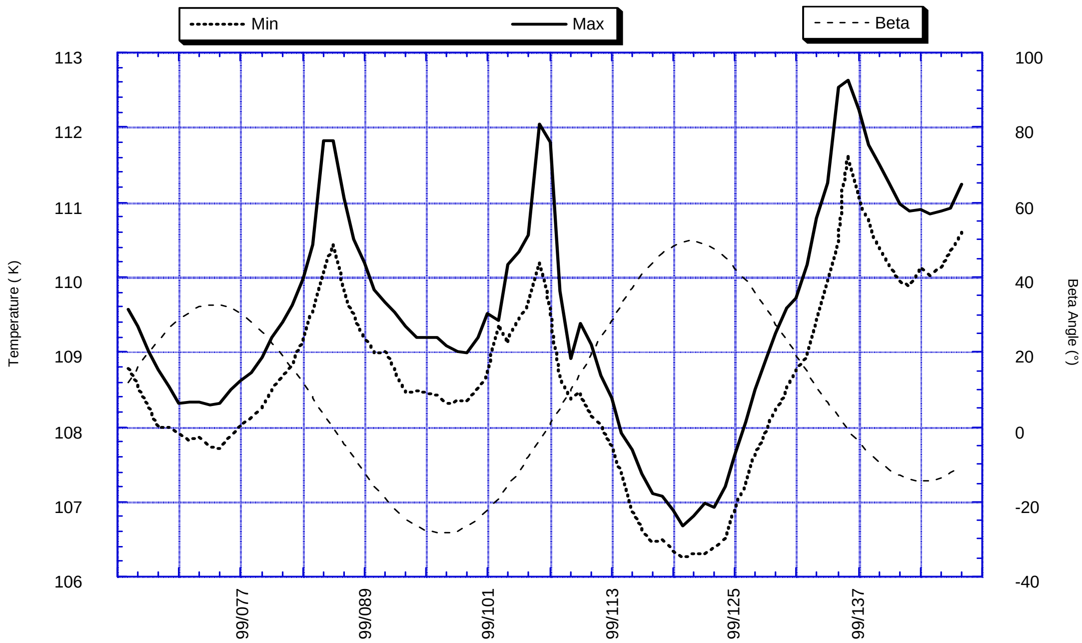


Figure 5.5-3 Cold Stage Temperature and Beta Angle

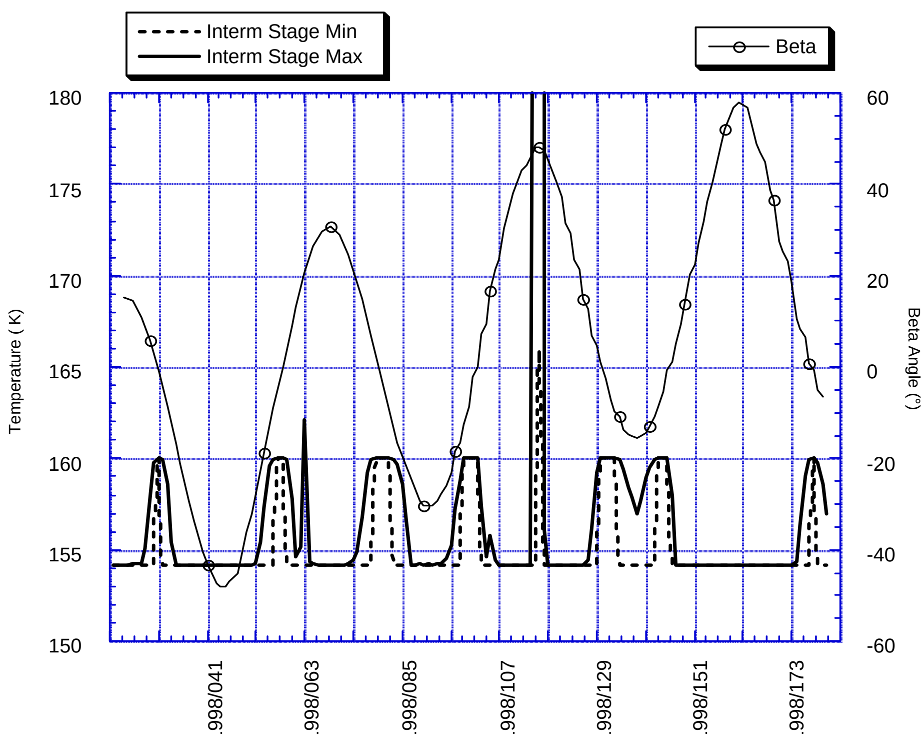


Figure 5.5-4 Intermediate Stage Temperature and Beta Angle

Appendix A: Anomaly Reports

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
1	11/27/1997	Cat Bed Temps	RCS	ISP Cat Bed temps (+pitch,T8), T5, T6,T7,T10 exceeded yellow high limits. At first, values did not exceed flight limits but RCS limits were not defined in PDBFIX. High temps may be due to the Sun (Sun Acq.) in present orientation.	8/25/1998	Closed
2	11/27/1997	TAM A Threshold Level	ACS H/W	ACS FDC tripped causing switch to TAM B. TAMs are not as noisy as expected, may be difficult to detect a failed TAM.	5/15/1998	Closed
3	11/27/1997	HGA Deploy.Main Hinge @91.08°	HGAS	HGA deployed, however telemetry reported the main hinge value of 91.08°.(TMM A) and 94.77° (TMM B). The nominal deploy status at 110°. Test data shows we are within 1 count of expected value.	5/15/1998	Closed
4	11/27/1997	Memory Scrub Errors	Flight SW	Continue to see correctable MS errors.	5/15/1998	Closed
5	11/28/1997	Receivers Unlocked During Madrid Contact	Com/RF	Detector lock on both receivers reported unlock during Madrid event.	10/19/1998	Closed
6	11/28/1997	Receiver Unlock with AGO	Com/RF	Dropped lock on receiver and uplink card lock during AGO event.	5/15/1998	Closed
7	11/29/1997	Late Acquisition	Com/RF	Late Acquisition scheduled event as coho but did not configure xponder to coho mode	5/15/1998	Closed
8	11/28/1997	Late Acquisition	Com/RF	The support beginning at 06:27 with TDS was set up with config codes of H03 J04 T24 - a coherent support. MOC called CSC - said that they did not have RF. We checked the config and it matched what CSC said - coherent.	9/11/1998	Closed
9	11/28/1997	Clock Correlation	MOC/RDD	There appears to be problems with the Clock correlation in the MOC. Can not adjust clock, in 4Kbps mode, until problem solved.	7/15/1998	Closed
10	11/28/1997	Receiver Dropping Lock	Com/RF	Issued XA1 mode 2 command and GCMR'd WSC to non-coherent. Issued RTN reacq and acquired. Note: After switch to non-coherent still saw receiver dropping in and out of lock.	4/6/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
11	11/28/1997	Unable to CMD at AGO	Com/RF	Unable to get commands into the s/c through AGO. The AGO events overlapped a TDRS event. Receiver 1 stayed lock on the TDRS signal throughout the event, and the subcarrier remained in the TDRS state (vice 16 kHz).	12/11/1997	Closed
12	11/28/1997	Tracking Data	Tracking Data	The PA reported (332/20:00 z) that all two-way tracking data since 03:40 z was invalid.	12/11/1997	Closed
13	11/28/1997	1773 Bus Error on S/C 1773 Bus to ACS Processor	Flight SW	Got one spacecraft 1773 bus error from the ACS Processor @ GMT 332-17:38	12/19/1997	Closed
14	11/28/1997	HGA tracked to software stop.	GSACE	During TDS event (GMT 333-00:21 through 333-01:01), HGA tracking and event were interrupted when the HGA's x-axis reached an ACS software stop at 90.2 deg. Event was terminated approximately 2 minutes early.	12/5/1997	Closed
15	11/29/1997	UPDs Not Working from MOC Initiation	Procedure	PA has to send OTM for MOC to start receiving UPD's,GCMR's, etc. During event 7, FOT coincidentally failed to string 3 (A TNIF was loaded after RDD on all 3 strings causing hangup). Went back to string 1, GCMR did not work.	7/27/1999	Closed
16	11/29/1997	TSM 19 and 20 Failed	Com/RF	The load had XPONDER 2 on for 21 min 03 sec, which triggered TSM's 19 and 20.	12/1/1997	Closed
17	11/28/1997	Receiver AGC Levels Varying Dummy Track.	Com/RF	During HGA dummy tracks the receivers AGC levels for 1&2 were varying and different.	4/17/1998	Closed
18	11/29/1997	Thruster Calibration	RCS	While performing the 10 second thruster cal, thruster 6 (ISP -Pitch) only reported 56 burn counts (vice 80).	12/11/1997	Closed
19	11/29/1997	ATS Jump Command	Flight SW	Uplinked an ATS jump command to the S/C ATS to avoid executing the LOS RTS (event extended to see how long we would remain locked after reaching the HGA software stop). Upon issuing the command (20:33:02), the Attached S/C event messages were received.	7/27/1999	Closed
20	11/29/1997	Solar Array Slew to Track in Sunlight	ACS S/W	Noted that S/A slew to track position was not complete when spacecraft entered sunlight portion of orbit. Appears to start approximately 1 minute late.	12/18/1997	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
21	11/30/1997	VIRS Time Code	VIRS	VIRS h/k science time tags stopped updating at 334-12:48 z. This is within the time frame of when we uploaded the VIRS patch and soon after power on. TSDIS reported science time tags not updating.	12/18/1997	Closed
22	11/30/1997	Ground Sync to S/C CLCW	MOC S/W	After DS16 event, sent command with wrong 'next expected frame sequence number.' Received transfer frame error on the s/c.	12/19/1997	Closed
23	12/1/1997	Receiver 2 False Locked	Com/RF	Receiver 2 false locked at 334-23:17. A similar false lock had been observed previously during mission simulation. The receivers are prone to false lock if the received signal strength is high.	12/11/1997	Closed
24	12/2/1997	Loss of I Channel Data After Acquisition	n/a	SGLT3 had a software problem. Lost lock on I channel at 05:36:44, never locked back up. Lost 18min. 16sec. of I channel data (32Kbps - recoverable). TTR# 19618 was written for the event. Next TDRS event experienced no problem with I channel data.	1/8/1998	Closed
25	12/3/1997	ACS Yaw Updates Alternating Between +0.3° and -0.3°	ACS S/W	The spacecraft updates its Yaw information at 6:00AM and 6:00PM each orbit. Since acquiring normal attitude the Yaw updates have been alternating +0.3° and -0.3°.	1/7/1998	Closed
26	12/4/1997	S/C Software Bus Error (Invalid VIRS Data)	Flight SW	S/C software bus error occurred between 338-03:57:49 and 338-03:58:21. Suspected cause is invalid stream ID from XS (03:57:53). Event occurred while OBS out of view, Lat.=-3°; Long=59°, ~10min after sunrise.	8/23/1999	Closed
27	12/4/1997	Data Drop-Out	Com/RF	At 338-15:44:23, 140 frames were missed during the recorder playback (VR2). OBS was located Lat=32.5° and Long=119°(E). During the same event, a sudden drop in the receivers AGC level was experienced (~15:49 - 15:50) when the OBS at Lat=35°; Long=1°	12/19/1997	Closed
28	12/5/1997	XPONDER 1 Loss of Command Lock	Com/RF	Command lock for XP1(A) went to UNLOCK for approx. 2 sec.	12/19/1997	Closed
29	12/5/1997	Telemetry Output (TO) Task Restart	Flight SW	Received a "Bad hdwr status caused tlm restart I:4005 Q:600b". Also, "STOQRESTRT=1", Q channel telemetry restart.	4/6/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
30	12/5/1997	No Acquisition at Start of Event (21:53 - 22:06)	N/A	No acquisition for entire event. Saw intermittent lock on Q channel towards beginning of event for a few seconds then dropping out. No 'I' channel observed (21:53 - 22:06).	2/17/1998	Closed
31	12/5/1997	Patch Overwrite	ATS Load	When uplinking a second patch to S/C_A, it overwrote previous patch.	4/12/1998	Closed
32	12/9/1997	Q Channel Restart (Same as Rpt. #29)	Flight SW	A 'Q' channel restart occurred at 97-343:06:58:56 due to a bad downlink hardware status of 'Q' channel. Status of 'Q' channel indicated X'600b', nominal status is X'400b'. Momentary dropped lock on 'I' channel.	4/17/1998	Closed
33	12/9/1997	Multiple Memory Location Bit Error	Flight HW	During the playback of the Event buffer a flight status message indicated that at 08:06:43 EDAC (Memory Scrub) detected a multiple bit error at address: 102e3988 in memory.	4/17/1998	Closed
34	12/9/1997	Recorder Overflow On VR#6 (VIRS)	VIRS	The first support of day 344 did not have enough time to dump all recorders (17 minute event). The length of the support was shorter than the dump duration. A blindacq was scheduled to finish the playback of VR#6 and also release data set #1 of VR#6	12/19/1997	Closed
35	12/10/1997	RX 2 Not Locked to PN Long Code.	Com/RF	Upon acquisition of event and throughout, receiver 2 was not locked to the PN long code. DOY 129 024630 (TDW) - Identical to DOY 344 occurrence. No operational impact. DOY 133 065200 (TDW) - Identical to DOY 344 occurrence. No operational impact.	5/13/1998	Closed
36	12/13/1997	EDAC Multiple Bit Error (same as report #33)	Flight HW	348/02:53:12, TRMM took an EDAC Multi Bit Error 93a712c I/O: MEM . 348/02:53:15 SMSTNONCU = 2 (Delta Limit) OBS was in eclipse and not in SAA at the time the upset was reported. 357/12:58:10 SMSTNONCU = 3 364/17:44:44 SMSTNONCU = 4 s/c was in sunlight	4/12/1998	Closed
37	12/16/1997	VIRS FPA Heater Power RH	VIRS	Virs FPH Heater Power out of Limits @ 350-05:02:55 VFPACTLPWR went YH @ 350-05:03:05 VFPACTLPWR went RH Limit reached @ 350-04:19:18.	10/14/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
38	12/12/1997	No Acquisition Event Start: 346-21:25 and Event Start: 346-23:03	Com/RF	Never saw lock on I or Q channel at AOS. Attempts to GCMR were unsuccessful (FWD REACQ). Attempts to toggle coherency were also unsuccessful. finally GCMR to NON-COHO to get lock on I channel. Event Start: 346-21:25 also occurred on the following event.	12/19/1997	Closed
39	12/13/1997	No Acquisition, WSC Reports No RF.(347-22:09 - 22:29)	Com/RF	No acquisition for entire event. WSC saw no RF. PSAT file showed we were not in view of TDW.	1/7/1998	Closed
40	12/22/1997	S/C Software Bus Error (Invalid TMI Data)	Flight SW	S/C software bus send error occurred at 356-08:04:10. The cause of the error count incrementing is an invalid stream ID, not defined in the SB table, received from XI . Event occurred during passage through the SAA. Similar event occurred on 97-338	1/7/2004	Closed
41	12/27/1997	Invalid VIRS Telemetry	VIRS	On 357:19:00:10 and again on 359:00:14:10, VIRS housekeeping telemetry seemed to be invalid. Telemetry indicated B-side heaters ON, scan drive ON and A side OFF, Safehold shutter closed, and rad cooler door in the outgas position.	4/9/1998	Closed
42	12/27/1997	ESA ORS high Voltage	ACS ESA	AAESAAORSVK read yellow high on numerous occasions on DOY 358 and 359. During this time, ESA quadrants 1 and 3 showed moon and Sun interference. Also, quadrant 3 showed OVER_RANGE on occasion for mnemonic AAESAA3RNGT.	4/22/1998	Closed
43	12/27/1997	TSM#29 Execution	Flight SW	On Day 359, TSM#29 executed incorrectly three times. It executed properly at 06:57, coinciding with time in eclipse, then executed incorrectly at 07:28, 07:52, and 08:15. It should have executed at 08:27, which it did not. It properly executed at 10:00	4/17/1998	Closed
44	12/27/1997	CERES -Stored Command Processor Interaction	CERES/ SCP	CERES instrument correctly safed itself when the SPS1 viewed the Sun. Commands to put CERES into short/normal scan seemed to execute approximately 5 seconds prior to command time in integrated print, however all AOS/LOS and PR commands executed	7/14/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
45	12/29/1997	Fail over to Redundant IRU	ACS H/W	At 362-18:45:12, FDC test 0 failed the first limit and took the action of switching to the redundant X-axis Gyro. The limit on this FDC test was 5 and the period was 500ms.	7/14/1998	Closed
46	12/29/1997	GSACE data	GSACE	Possible invalid data came out of the GSACE for one telemetry update. Various GSACE limits seen for one packet, then went back within limits. The following limits were seen for one packet update: GASAMYABSH=Enabled GASAMYEOT=@_EOT GASAMYGLITCH=Glitch	9/19/1998	Closed
47	12/31/1997	Framer Error on S/C Processor	Flight SW	001/ 11:27:50 P/B S/C PRI 08230 SFR204 unframing 'AP_A synch' bad checksum=0001 001/ 11:27:51 P/B S/C PRI 08231 SFR203 unframing 'AP_A synch' seq gap=1 exp=34C1 got=34C2 058/ 20:51:02 P/B S/C PRI 04931 SFR204 unframing 'AP_A synch' bad checksum=0007058	4/5/1999	Closed
48	1/3/1998	Bogus Reading On WABSOC1EOD & WABSOC2EOD	Flight HW	WABSOC1EOD was reading a RED LOW value of 87.8018119 & WABSOC2EOD was reading a RED LOW value of 87.7972342 It is currently believed to be a glitch in the PSIB side A.	7/14/1998	Closed
49	1/8/1998	PSIB Side A Battery 2 SOC Tripped TSM 2	PSE	The MOC received the following playback s/c events: 008/00:50:58 7071 P/B S/C PRI 09695 STS403 Limit changed threshold; id=2 thresh=0 008/00:50:59 7071 P/B S/C PRI 09695 STS403 Limit Returned to Normal; id=2 thresh=4	1/28/1999	Closed
50	1/13/1998	Primary S/C 1773 Bus Error / Invalid Stream Id From XI	Flight SW	S/C software bus send error occurred at 014/00:20:49. Error happened in real-time, S/C was not in the SAA and no instrument commands were being executed out of SCP. The cause of the error count incrementing is an invalid stream ID.	7/14/1998	Closed
51	1/23/1998	Primary S/C TC Mode	Flight SW	The S/C TC mode toggled between FLYWHEEL State and NORMAL State for 3sec.	7/14/1998	Inactive

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
52	1/23/1998	FDC Test 93 Aborted Delta-V	ACS S/W	Delta-V aborted due to FDC test 93 reaching its limit. FDC 93 aborts the burn when body momentum Y-axis (pitch) reaches 30 Nms for 3 updates (3 updates in 8 hz mode is 375ms.) Delta-V aborted after 84 pulses (82 pulses on thruster 2) which is 10.5 sec.	7/14/1998	Closed
53	1/25/1998	EPV Failed Continuity Check.	ACS S/W	On 025 at 0100 the daily epv loaded to execute at that time failed due to a continuity check for position (X,Y,Z).	7/14/1998	Closed
54	2/10/1998	XP2 Loses Offset	Com/RF	Transponder 2 loses the frequency offset after the first event. The offset is observed during the first succeeding event, but is lost after that event, presumably in the deacquisition.	7/15/1998	Closed
55	2/13/1998	Battery 2 Cell 1 Hitting YH and RH limits	PSE	WAB2C1V hitting YH limits since Day 028, first noticed during real-time on Day 040/07:00:16. Limits seen during real-time: 98-028/19:12:41 WAB2C1V = 1.49318448 (YH for 1 min) 98-030/19:59:11 WAB2C1V = 1.49318448 (YH for 1 min) 98-036/08:31:16 WAB2C1V = 1	9/11/1998	Inactive
56	2/13/1998	VIRS Instrument Reset	VIRS	VIRS instrument reset itself at approximately 98-044/12:48:51z. This is believed to occur with a VIRS watchdog timeout and warning event #20. 12:49:07 Invalid stream id from the spacecraft bus 12:49:13 VIRS enters DAY mode 12:49:13	3/8/1999	Inactive
57	2/14/1998	PRP Line 8 LBS@B-Roll Went Yellow High	RCS	98-044-08:29:10 RA_LN8_T = 35.5033 Yellow High and returned within limits @ 98-044-08:29:10 to 34.6315. 98-044-11:37:26 RA_LN8_T = 35.5033 Yellow High and returned within limits @ 98-044-11:38:30 to 34.6315. 98-044-16:10:30 RA_LN8_T = 35.5033 Yellow High	5/15/1998	Closed
58	2/19/1998	XPONDER Loss of Command Lock	Com/RF	Command Detector lock for XP2 (A) went to UNLOCK for approx. 1 sec. 1. @ 18:56:57z _2. @ 19:02:51z Command Detector lock for XP1 (A) went to UNLOCK for approx. .5 sec. 1. @ 19:08:09z TTR#: 19708	5/15/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
59	3/9/1998	Low Power Tripped	PSE	On DOY 062, Low power was tripped at 21:30:28z when SOC for batteries 1 and 2 went below 70%. All instruments were powered OFF with the load shed RTS (RTS#2 and #15).	7/14/1998	Closed
60	3/9/1998	EPV West and West BackUp Failed Continuity	ACS S/W	EPVs for TDRS West and TDRS West Backup failed continuity in position and velocity. TDRS East and TDRS Spare were uplinked with no errors.	9/11/1998	Open
61	3/9/1998	Dropped Telemetry Packets	Flight SW	Dropped telemetry packets during 1/4K events. 14:41-14:44z # of packets dropped from 211 - 627 15:05-15:08z # of packets dropped from 628 - 1171 15:53-15:56z # of packets dropped from 1173 - 1395 16:19-16:22z # of packets dropped from 1396 - 1773	5/15/1998	Closed
62	3/9/1998	Missing PR Packets	PR	Missing packets were noticed by Pacor on DOY 065 at the following times: 15:53:41 - 15:53:49 13 packets 15:54:27 - 15:54:35 13 packets	7/17/1998	Closed
63	3/10/1998	SC TC Valid Correlation Flag	Flight SW	On day 065 at 16:14:11, the discrete mnemonic STCVCORR toggled to FALSE. The SC Time Code Valid Correlation Flag is normally set to TRUE. After one update it returned to its nominal state.	8/16/1999	Closed
64	3/10/1998	LBS +YAW (T3) Valve Temperature	RCS	Following the LBS DeltaV maneuver pair on day 065, the +Yaw Valve Temperature (T3) exceeded the Yellow High value of 35 degrees, peaking at 36.41. It took several orbits to cool down to a level within the nominal limit condition.	7/14/1998	Closed
65	3/15/1998	WANEBI Went YH during 2nd Delta-V Burn	PSE	@ 074/18:29:23, WANEBI went to 26.037 Yellow High for one count, one second after the second delta-V burn was initiated. It also went to 25.35 amps Yellow High from 074/18:29:33 to 18:29:42.	4/2/1999	Closed
66	3/31/1998	TMI Multiple Errors and Retries	TMI	TMI retry @19:07:30(5)_TMI retry @19:09:04(6) TMI remote terminal errors incremented @ 19:09:37 Invalid stream ID (a3cax) from XI @ 19:08:52 resulting in a Spacecraft software bus send error counter to increment to 1 (YH). The invalid stream ID due to TMI	7/17/1998	Closed

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
67	4/25/1998	S/C to Sun Acq Mode	ACS S/W	Due to dual sun and moon interference in ESA quad 3 FDC TEST 83 tripped twice the put the S/C in Sun Acquisition Mode.	7/14/1998	Closed
68	6/28/1998	Pri S/C Memory Scrub Presence Flag Not Present for 4 seconds	Flight SW	Received Yellow Status (N) on Primary S/C Memory Scrub Presence Flag @ 179/031526 for 4 seconds. Status then went back to Nominal Status (Y) @ 179/031530. This event occurred as we were releasing Data Set 1 after completion on Data Storage Playback.	7/14/1998	Closed
69	8/18/1998	CERES Data Acquisition Assy. (DAA) High Voltage Indication	CERES	230-10:53 GMT - At AOS an event message showed that the CERES Data Acquisition Assembly (DAA) had reached 15.9324 volts (CDAAP15V) since LOS of the previous event (09:35 GMT). Voltage returned to acceptable level of 15.6981 volts at 11:08:46 GMT.	4/2/1999	Closed
70	10/16/1998	Lost Upl-1 Receiver and Detector Lock Status and Uplink CLCW Bit Lock Status	Com/RF	074025 XA1CMDLK went unlock for 2 seconds 074025 SCIAV1NB went to unlock for 4 seconds 074025 SCIAV2NB went to unlock for 4 seconds 074025 SCIAXLAS went to unlock for 4 seconds 074025 SCIBXLAS went to unlock for 4 seconds 074025 SCIBV1NB went to unlock for 4 seconds.	7/27/1999	Open
71	1/7/1999	Sun Acq Tripped & GSACE B Switched	ACS S/W	On Day 003, FDCs 112 and 113 tripped, two minutes after Delta-V maneuver 68 burn 1 completed. The maneuver occurred in sunlight, so the arrays remained stopped for 41 seconds, at an angle of 37°.	3/4/1999	Closed
72	5/17/1999	TSM #32 Battery 2 End of Day State of Charge Tripped	PSE	On 99-137 at 16:34:11z, TSM #32 Bat 2 EOD SOC tripped causing RTS#13 to execute at 16:35:11z. The Battery-2 SOC counter fell below 95% to 94.99%. The Battery 1 EOD SOC TSM tripped on 99-138 at 06:17:11z.	8/2/1999	Closed
73	5/18/1999	PSIB-A Orbit Status Unchanged	PSE	PSIB side A orbit status (day/night indicator or flag) remains in day mode throughout every orbit and the end of day/night SOC counters (although the BSOC counters are operating nominally) for both batteries are currently not updating.	7/27/1999	Open

#	Date Opened	Title	Subsystem	Description	Date Updated	Status
74	6/13/1999	Mag Torque Coil Control	ACS H/W	During the back orbit before the doy 164 2345z TDE support FDC test 9 & 12 hit their first threshold, then FDC test 9 reached it threshold again and kicked in FDC action 23. FDC test 9 & 12 monitor MTB X axis MAG TORQ cmd ACE-A & B.	7/27/1999	Open

Appendix B: Event Reports

#	Date Opened	Title	Description	Date Closed	Status
1	12/22/1997	UPD Outage at NCC	356/202100 - 202300 - 2 minute UPD outage 356/204906 - 205116 - 2 minute UPD outage 356/222100 - 224100 - Lost UPDs for entire event.	9/16/1998	Closed
2	12/24/1997	Mutual Interference	About 14 minutes into the event, the MOC experienced data drops on the Q channel and this lasted till the end of event.The data drop outs started a few minutes after all data sets had been dumped and released.	9/16/1998	Closed
3	12/24/1997	Late Acquisition	Had a 1 minute 38 seconds of late acquisition during the 358/1743z event. No data was lost, all VCDUs were recovered. TTR#: 19639	9/16/1998	Closed
4	12/30/1997	GTAS Workstation Locked Up	While a rar file was being processed, the level0 file arrived from DDF. At this point the GTAS workstation locked up completely where the FOT couldn't bring up a Hpterm, iconify the main menu, or move the mouse pointer.	9/16/1998	Closed
5	1/5/1998	Front End Processor Failure	Front End Processor 1 failed prior to AOS of event @ 11:18z. OTHER OCCURRENCES: 1. Front End Processor 1 and 2 failed in the middle of the 048/14:10z event with orbit# 1287. Was unable to command spacecraft for the rest of the support. No Data was lost	9/16/1998	Closed
6	1/13/1998	Late Acquisition	1 minute 37 second late acquisition during 017/1749 TDW SSA2 event. No impact. Generic TTR # 19639.	9/16/1998	Closed
7	1/19/1998	RAID Failure	0215z, RAID failed 2 minutes prior to AOS. Unable to access any workstation or xterminal on string 1. Took event on Backup string . RAID recovered without FOT intervention. Took next 5 events without incident on prime string.	9/16/1998	Closed
8	1/20/1998	LTS Port #3 Trouble / String Failover	During break prior to 1902z pass, maintenance decided to troubleshoot the LTS Port #3 known problem. Efforts included connector replacement, cable exchange, interface board removal/replacement.	9/16/1998	Closed
9	1/26/1998	Event Not Supported By FOT	The FOT failed to support the TDE event scheduled at 026/0049z. Operations were busy with the end of day archiving and reports and failed to realize the upcoming support.	9/16/1998	Closed
10	1/26/1998	Late Acquisition	Late acquisition for event scheduled at 110030z. Signal was acquired at 110130z. Generic TTR#19639 1minute 32k data loss - recoverable	9/16/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
11	1/28/1998	Unable to Command - TR1 Line Pulled at NASCOM	130800 - 132625 -Unable to command entire event. NASCOM had TRMM TR#1 reconfigured for an unspecified test. MOC was able to complete retransmits and DS release on following event. No impact. TTR# 19677	9/16/1998	Closed
12	1/28/1998	Five Minutes Unable to Command - Return Chain B to A Failover at WSC	211905 - 212427 MOC lost commanding during real-time ops due to Return Chain B to A failover at WSC. No impact.	9/16/1998	Closed
13	2/6/1998	Late Acquisition	Late acquisition for event scheduled @ 143847z. Signal was acquired @ 144029z. Generic TTR# 19639. 1 min 12 sec 32k data loss - recoverable.	9/16/1998	Closed
14	2/19/1998	Unsuccessful Blind Acq. on TDS	On an attempted blind acquisition with TDRS Spare, the MOC did not acquire. Upon doing a replay of the data, it was observed that the receivers did not lock cleanly on the forward until approximately ten minutes before the end of the event	9/16/1998	Closed
15	2/23/1998	Forward Link Failover at WSC	WSC had to failover the forward link ground equipment, reason is unknown - under investigation. TTR # 19713	9/16/1998	Closed
16	3/4/1998	Failure to Acquire on 1/4k Event	On day 063, the MOC did not acquire on the 1/4k event scheduled at 16:11. WSC was locked on the I-channel at AOS. Five minutes into the event, the FOT determined that the event was scheduled for 1/1k while the spacecraft was configured for 1/4k.	9/16/1998	Closed
17	3/6/1998	Raid Failure	String one and string three inaccessible due to raid failure. Raid monitor shows failure to read platter 2a.	9/16/1998	Closed
18	3/9/1998	Loss of I Channel Data At AOS	Lost lock on I channel at AOS. 1min. 57sec of I channel data (32Kbps) was affected but it's recoverable. TTR# 19639 was written for the event. Next TDRS event experienced no problem with I channel data.	9/16/1998	Closed
19	3/9/1998	RAID Complete Failure	On March 6, 1998 the RAID experienced a catastrophic failure which rendered it permanently inoperational. At about 5:00AM there was a burning smell noticed in the MOC and shortly after the RAID completely failed.	9/16/1998	Closed
20	3/10/1998	Five Minutes Loss of Commanding	Event began nominally at 2025z and a SCINOOP command was successfully sent and verified at 2026z. At 203330z, after playback was complete, a retransmit command (SDSRXSEQ) was attempted but was unsuccessful.	9/16/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
21	3/14/1998	Late Acquisition on TDW Event	MOC failed to acquire at AOS during event scheduled for 0953z. A GCMR was sent for forward reacquisition at 0954z and the MOC locked on data at 0955z. TTR# 19639 (generic) was assigned to this case. Approx. 1 min 40 sec. 32kbps data loss - recoverable.	9/16/1998	Closed
22	3/22/1998	Last 12 Minutes of Event Unusable	At approx 19:50:40 we started getting lots of missing VCDU's (see event snap), then we started getting lots of 'Return link 2 xxx frames overflowed' (where xxx equals various numbers from 1 to several hundred). About this time we stopped logging VCDUs.	9/16/1998	Closed
23	4/3/1998	Late Acquisition	Did not acquire at scheduled AOS (09:06), sent a GCMR: FWD REAC and locked up 2 minutes into the event (09:08 AOS). Received data in time for playback but missed event buffer dump. CSC 2 assigned TTR # 19639 to the discrepancy.	9/16/1998	Closed
24	4/3/1998	Bad Vectors at WSC for TDE	WSC received bad vectors for TDE which caused WSC to lose lock on TRMM @ 19:04:02. This resulted in 12 minutes & 58 seconds of recoverable data loss. TTR # 19824	9/16/1998	Closed
25	4/11/1998	SCP Load Discrepancy Re-configured Spacecraft	At the scheduled AOS of the first event on Day 101 (00:50 - nominal 32/2048 kbps event) the spacecraft was not acquired. After trying a couple tnif loads it was determined that Reed-Solomon (RS) encoding had been disabled on both channels.	9/16/1998	Closed
26	4/14/1998	Generic Late Acquisition	Late acquisition for event scheduled at 001200z. Signal was acquired at 001350z. Generic TTR#19639 1 minute 20 seconds 32k data loss - recoverable.	9/16/1998	Closed
27	4/15/1998	Reed Solomon & Sequence Errors	Had a very large number of Reed Solomon and Sequence errors (in the 300's) in VR 4 and 6. It was so large to retransmit during the 2123z event. PACOR received every frame and our records also indicate there was a Mutual Interference during that support.	9/16/1998	Closed
28	4/21/1998	20 Second Real-time Data Dropout	MOC experienced a 20 second data dropout from 111/17:38:45 to 111/17:39:05. This was due to a Forward Link Failover at WSC at that time. No impact on operations. TTR# 19059 generated.	9/16/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
29	4/22/1998	GENSSR Failure	String 1 failure when trying to rexmit missing vcdus (also during the same pass the S/C ATS load did not compare the checksums). Time ran out of the pass before the release data set command could be sent.	9/16/1998	Closed
30	4/22/1998	CERES To Safe Mode	At doy 113 00:01:11z CERES commanded itself to Safe mode due to the Solar presence sensor #1 sensed the Sun. Alongtrack operations were started during a Sun elevation of -1°, this is during a solar avoidance region.	9/16/1998	Closed
31	4/25/1998	S/C to Sun Acquisition Mode	At Doy 115/031401 TRMM entered Sun Acq Mode due to dual sun and moon interference in ESA quad 3. The S/C aborted the current ATS, feathered the HGA and SA, and turned off all 5 instruments.We failed to acquire at 0418 TDW and all attempts at blind acq.	10/1/1998	Closed
32	4/26/1998	Data Loss	Spacecraft experienced Mutual interference during the 116/04:45z support causing the loss of the Q channel. Dump was in progress when we had the interference which lasted for a couple of minutes. It affected the dumps in VRs 3, 4, 5 & 6.	10/1/1998	Closed
33	4/25/1998	CERES Not Configured Completely During Power-ON	During recovery from Sun Acquisition/ load shed, CERES was not re-configured properly during Power ON. The scan rate was at the default and should be set to a count = 913 (6 °/sec) also the solar cal azimuth position was at the default.	5/5/1998	Closed
34	4/27/1998	Transfer Frame Errors and Aborts During Uplink of Daily SCP Load	During initial attempt to uplink the daily SCP load (117-20:27 GMT), 7 transfer frame errors and 2 transfer frame aborts occurred. Neither mutual interference nor SAA was reported to have been present during this event.	5/19/1998	Closed
35	5/1/1998	Catbed B-side Heaters ON	During the event prior to the Delta-V #25 burn, the RTS which controls the Cat Bed heater power-on had not be enabled. Several minutes after AOS for orbit 2440 the Delta-V RTSs were enabled, and the command to power on the catbed heater was sent.	10/1/1998	Closed
36	5/10/1998	Generic Late Acquisition	Late acquisition for event scheduled at 061100z. Signal was acquired at 061252z. Generic TTR#19639 1minute 22 seconds 32k data loss - recoverable.	10/1/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
37	5/10/1998	Lost UPDs from NCC	Lost UPDs from the NCC @ 205630 to 211352. Notified PA. then turned upds on again , did a gcm init then sent a comm test message. MOC then began successfully receiving upds. No clock delta was calculated for this event. No other impact.	10/1/1998	Closed
38	5/28/1998	Data dropout	Intermittent data loss on I and Q channels during a 1/4K event for approximately 2 minutes (01:14:26-01:16:18). CSC 1 was notified and noticed dropouts on both their prime and backup siglets. After the discrepancy the event ended with no further problems.	10/1/1998	Closed
39	6/9/1998	Recorder - Overflow	TDS developed some problems so all supports on TDS were either deleted or replaced. We had a very long playback during the 160/15:36z event. The Data was from two of the supports that had been deleted earlier due to the TDS problem.	10/1/1998	Closed
40	6/18/1998	Late Acquisition	TRMM had a 1 minute 4 seconds of late acquisition during the 0054z event. No data was lost, all VCDUs were recovered. TTR#: 19639	10/1/1998	Closed
41	6/21/1998	DS Recorder overflow	TRMM experienced some load problems on day 98-172 which made it impossible for the S/C to be acquired during the 172/00:42z event.The S/C ATS load for DOY 98-172 was not properly uplinked. e S/C automatically configured itself to low data rate.	10/1/1998	Closed
42	7/1/1998	Negative Acquisition / Computer Failure at WSC	No Data received for scheduled 1 and 4 k event from 0941 to 0951z. MOC was notified that WSC was experiencing computer problems on site. Ref: TTR # 20031.	10/1/1998	Closed
43	7/2/1998	Negative Acquisition / Ground Equipment Failure at WSC	Event scheduled with TDE at 0155z did not take place due to a ground equipment failure (Tracking and Telemetry Commanding computer) at WSC. CSC 4 warned TRMM MOC personnel about said failure approx. 15 minutes prior to scheduled event.	10/1/1998	Closed
44	7/2/1998	GCMR	Wrong GCMR was sent during the 16:38z event. It was quickly corrected, and there was no impact to operations.	10/1/1998	Closed
45	7/7/1998	Late Acquisition	TRMM had a 1 minute 35 seconds of late acquisition during the 188-1347z event. No data was lost, all VCDUs were recovered. TTR#: 19639	10/1/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
46	7/8/1998	Late Acquisition	TRMM had a 1 minute 21 seconds of late acquisition during the 189-0035z event. No data was lost, all VCDUs were recovered. TTR #19639	10/1/1998	Closed
47	7/12/1998	Generic Late Acquisition	Generic late acq at the 0348 support TTR #19639 Locked up on data at 193-035032	10/1/1998	Closed
48	7/13/1998	Return Link dropout	16 second return link dropout - reason unknown. All data recoverable. TTR #19640	10/1/1998	Closed
49	7/22/1998	Late Acquisition	TRMM had a 1 minute 12 seconds of late acquisition during the 0934z event. No data was lost, all VCDUs were recovered. TTR#: 19639	10/1/1998	Closed
50	7/22/1998	Late Acquisition	TRMM had a 52 second late acquisition during the 1743z event. No data was lost, all VCDUs were recovered. No Forward reacquisition GCMR was sent - TTR#: 19639.	10/1/1998	Closed
51	7/24/1998	Unable to Command - Misconfiguration by NASCOM	During the event beginning at 1517z, MOC personnel were unable to send commands to the spacecraft after AOS until about 10 minutes into the event. Prior to the event, MOC personnel requested that NASCOM configure the SOTA for possible failover.	7/24/1998	Closed
52	7/30/1998	Loss of Commanding During IP Test	For the following IP test events there was loss of commanding 210/1814-1824 TDS - no commanding for entire event 210/1851-1901 171 - 6 minute 16 second command loss For more information refer to attached e-mail and TTR# 20112	7/30/1998	Closed
53	8/8/1998	Lost Lock on Data 57 Seconds Prior to Scheduled LOS	At 57 seconds prior to scheduled LOS we got a CRC error and I & Q channels dropped out. We did not reacquire for the remainder of the event. 57 seconds of 32 kbps data lost, recoverable. The data is recoverable at WSC (tape # w8171). TTR # 20132	10/1/1998	Closed
54	8/31/1998	Data Dropout During Non-Coherent Support	During non-coherent (1k/4k) support scheduled for 243/07:07 GMT, lost transponder 2 command and receiver lock. Dropout occurred at 05:36:18 GMT for 14 seconds.	10/1/1998	Closed
55	9/3/1998	Did Not Acquire Throughout Entire Critical Support.	Did not acquire through out entire critical event. TTR #20173	10/1/1998	Closed
56	9/15/1998	Failover to String 2 - State Manager Crash	State Manager crashed on String 1 on 98-254 for the 15:50 event.	10/1/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
57	9/16/1998	20 Second Real-time Data Dropout	MOC experienced a 20 second data dropout from 111/17:38:45 to 111/17:39:05. This was due to a Forward Link Failover at WSC at that time. No impact on operations. TTR# 19059 generated.	10/1/1998	Closed
58	9/16/1998	Data dropout	Intermittent data loss on I and Q channels during a 1/4K event for approximately 2 minutes (10:32:00-10:34:00). CSC 3 was notified and noticed dropouts on both their prime and backup siglets. After the discrepancy the event ended with no further problems.	10/1/1998	Closed
59	9/16/1998	Loss of Event Due to TDRS 171 SALT Problem	Event scheduled to begin at 17:54:00 GMT was lost due to a handover problem between SGLT 4 and SGLT 5. TRMM MOC personnel scheduled a blind acquisition event at 1823z on TDS.	10/1/1998	Closed
60	9/26/1998	Unable on Command/ Failed Over to Backup/ Lost Continuity Files During Postpass Copy	Unable to command on prime string during event. Reconnect of TSTOL failed on both Workstations. Continuity files and end of pass files did not transfer from string 3 to string 2.	10/1/1998	Closed
61	9/26/1998	Demux problem at NASCOM after Reconfig back to Legacy. 9 Minutes Unable to Command.	This was our first event after reconfiguring to Legacy from the 48 hour IP test. MOC was unable to command from 121536z to 122456z. MOC did initially get a Noop into the spacecraft at AOS prior to the demux failure at NASCOM.	10/1/1998	Closed
62	9/27/1998	Prime String (string2) Quit Processing 'Q' Channel Data	The prime string (string2) quit processing 'Q' channel data during the VR4 playback. We first noticed the frames on the framestat page stopped updating. No data lost.	10/1/1998	Closed
63	10/12/1998	TDRS 171 S/C Emergency/Loss of supports	On doy 284 TDRS 171 experienced s/c problem and went critical, all supports on 171 were canceled. TRMM support at 2200z was rescheduled as a TDW at 2212z. During the support we ran out of view of TDW	4/2/1999	Closed
64	10/12/1998	Unsuccessful Coherency Switch on 98-279	Unable to gcmr WSC to Non coherent mode during a scheduled coherency switch due to loss of gcmr capability at the NCC. The PA attempted to send the gcmrs for the MOC but was unsuccessful.	4/2/1999	Closed
65	10/17/1998	IP Problem	Dropped lock on the Q channel due to PTP problems during the following events: 290/16:38:00-16:58:00 and 290/17:43:00-18:01:00. No data was lost. TTR #20284.	4/2/1999	Closed
66	11/2/1998	Late Acquisition	Late acquisition during the 0240z 171 support. 2 min 39 secs 32k data loss -- recoverable._TTR# 20314(UNKNOWN)	4/2/1999	Closed

#	Date Opened	Title	Description	Date Closed	Status
67	11/6/1998	Config Codes for 1/4K	Due to the shuttles need to use TDS, the 1/4K event which was scheduled for TDS was moved to TDE. The config codes H05 J25 T25 were used to reschedule the support, however the codes were not for 1/4K. They were for 1/1K.	4/2/1999	Closed
68	11/12/1998	TRMM Daily EPV Continuity Failure	The TRMM Daily EPV which is uplinked each day at 20:00z failed in position (pos=1, vel=0) continuity. Further trending revealed that position would have failed over a several hour period in X and Y axes by as little as 3 km or as much as 18 km	4/2/1999	Closed
69	11/13/1998	IP Problem	Approximately 8 minutes into the pass we experienced major dropouts of I and Q channel data. TTR#20365	4/2/1999	Closed
70	11/15/1998	FE or TSTOL Problem	String 2 (backup) disconnected itself, and was no longer decomming data during a pass. UPDs were also not being received after that point, there was no change in the system with respect to string 2's (Primary) operations.	4/2/1999	Closed
71	11/19/1998	Loss of I Channel on 98-323	After NCC98 testing on 98-323, all of PTP#2 was Disabled, which caused I Channel data (configured to PTP#2, Channel#4) to be unavailable for the event at 20:00z (TTR #20392). The problem was fixed upon a reset and re-enable of PTP#2.	4/2/1999	Closed
72	11/20/1998	Forward link failover	TRMM MOR lost telemetry at 07:12:59z for 15 seconds WSC did an automatic forward link failover at 07:13:11z (reason for failover is unknown at this time per CSC4) TRMM MOR received at 07:13:36z 15 seconds 32k data lost, recoverable TTR # 20393	4/2/1999	Closed
73	11/22/1998	TR3FE1	False data was received during the 11:18z pass. At 11:21:27 false EVD data was received (showed EVDs 1 ,2 ,3 ,4 ,5 6 ,9 ,10 ,11 &12 were ON and 7, 8 were OFF 'Nominal'), data was checked against string 2 and was shown to be false.	4/2/1999	Closed
74	11/28/1998	TR2WS2 Disk Drive Failure	TR2WS2 experienced a failed internal hard drive fan. This is the backup Oracle workstation, and it also is host to the /hist2 external hard drive, on which many archived delogs are stored.	4/2/1999	Closed
75	11/30/1998	Event Not Supported By FOT	The FOT failed to support event because the countdown clock was incorrectly set and as a consequence the procedure 'UTRMMUP' was not run. All data was recovered on the subsequent pass.	1/14/1999	Closed

#	Date Opened	Title	Description	Date Closed	Status
76	12/1/1998	Data dropout to POCC	During the TDE support at 335/0726 data started to degrade on the I and Q channels at 074003, and completely dropped out on the I channel shortly there after. CSC at WGStT confirmed good data leaving their site, and that they were recording.	4/2/1999	Closed
77	12/6/1998	No Data to POCC	We were notified moments before the scheduled start of the 1346 171 support that WSGT had a ADPE shutdown while our support was being loaded into it. This caused us not to have a RTN service.	4/2/1999	Closed
78	12/15/1998	No Response From State Manager / Rtn Link Overflows During VC 6 PB	TR2WS1 crashed during playback of VC6 data. Frame statistics quit updating and received No Response from State Manager /Return Link Frame Overflow messages and finally telemetry dropout message @092922z. Took snaps. Reason unknown at this time.	4/2/1999	Closed
79	12/25/1998	WSC Equipment Problems	The integrated receiver 'hung up' (CSC2's words) on the prime equipment chain and the auto-handover to back-up chain did not occur. CSC2 had to force a manual handover to the back-up equipment chain. We acquired at 20:12:20 12 minutes, 50 seconds dat	1/13/1999	Closed
80	1/1/1999	Year Changeover Problems	At the year changeover from 1998 to 1999, all equation processing became invalid on all strings until they were rebooted. Equation processing then worked nominally. At the year changeover from 1998 to 1999, all three front ends (FEPs) had to be reset	1/13/1999	Closed
81	1/13/1999	0955/TDW Event Shortened Due to UARS Going to Critical Status	013/0935z -MOC was notified from NCC Scheduling that UARS spacecraft had just gone to critical status. TRMM would only be given the first 3 minutes and 30 second of our scheduled 20 minute event. Received S/C event buffer dump and VRs 1 and 3 playback	1/13/1999	Closed
82	1/14/1999	FEP 3 Had Loose Wire	FEP 3 could not be used to take passes on 1/13/99.	1/14/1999	Closed
83	2/15/1999	No Q-Lock following COHO Switch	Following the coherency switch with TDRS West on 99-044 at 03:05z, the Q-channel never locked up at the MOC. WSC confirmed they had solid lock, and all GCMRs were confirmed as accepted.		Closed

#	Date Opened	Title	Description	Date Closed	Status
84	2/15/1999	STGT Line Outage	On 99-045, STGT experienced a temporary line outage which prohibited the MOC from receiving UPDs or sending GCMRs. USCCS Clock Updates were not received for the 05:09z and 05:47z events, and the GCMR for the 05:47z coherency switch was sent by WSC	2/15/1999	Closed
85	2/18/1999	Late Acquisition	Did not lock up properly at the schedules AOS. We were getting indications of Q-Channel data, but it was not steady. We were getting no I-Channel at all. 9 minutes 5 sec 32 and 2048k data loss all recoverable - TTR # 20602	2/18/1999	Closed
86	2/19/1999	TRMM Daily EPV Continuity Failure	Recurrence of Event Report 68, in which the daily EPV failed in the Y axis position by only 3 km (s/c was greater than the ground vector).	4/2/1999	Closed
87	2/20/1999	Timing Problem at WSGT	On 2 supports; DOY 052 at 01:45:51z and 03:16:47z, TDW WGST experienced a 4 second hit in their timing. We took a hit to the CI, no data drop just a page full of red and yellow limits that went back green after 4 secs. TTR#20619	4/2/1999	Closed
88	2/25/1999	Faulty Fan Replaced on String #3 Drive	String 3 disk drive was making a grinding noise and was reported faulty to maintenance. This was the bottomdisk drive next to the TRMM server.	4/2/1999	Closed
89	2/25/1999	No Q-channel or UPDs	At the start of the DOY 056 2322a tde support the PTP in the IP NOCC faulted knocking out our Q-channel and our UPD line. The PTP was rebooted and the Q and UPD's came in house. We got the Q and UPD's at 233159z. No data loss.	4/2/1999	Closed
90	3/6/1999	TR1WS1 TSTOL Crash	TR1WS1 Tstol failed to respond. Failed over to TR2WS1 for support. No impact.	4/2/1999	Closed
91	3/6/1999	Consim Error on Level0 Product Delivery Using New Disk	Received the following error messages on the consim window during Level0 product delivery from DDF. Mar 6 at 04: 15: 07 dsu check disk overflow Detected an overflow! Amount of disk space available=0.0 amount of disk requested = 122370856 bytes	4/2/1999	Closed
92	3/5/1999	Root disk failure on TR2WS3	The TR2WS3 Root Disk seemed to have failed, and did not properly reboot after 2 tries.	4/2/1999	Closed
93	3/8/1999	Ground System Misconfiguration	An incorrect TDRS was used to send a GCMR during a coherent switch.	4/2/1999	Closed

#	Date Opened	Title	Description	Date Closed	Status
94	3/24/1999	S/C Misconfiguration	At the TDW support on doy 083 0113z the High Gain Antenna was pointed at the wrong TDRS. A patch was sent to the ATS to elongate a support originally scheduled for 083 0116 for 20 mins. It was switched to start at 0113 for 23 mins.	4/2/1999	Closed
95	3/29/1999	Unknown MI	On DOY 088 in the 0533 TDE SSA 1 event we encountered severe dropouts due to unknown MI. This caused unusually high number of retransmits plus due to a long playback there was not enough time to release DATASET 1 with the exception of VR4.	4/2/1999	Closed
96	3/31/1999	Deleted Event still Held by NCC	An event was deleted at the MOC but had to be manually deleted by the NCC also due to a rejection (tolerance was too tight). However, NCC forgot to delete the event at their end, and WSC did not perform a pre-event briefing.	4/2/1999	Closed
97	4/2/1999	Test Load Overwrote Real S/C Load	Due to Y2K testing, a test Delta-V Load was transferred to the prime string and uplinked to the spacecraft. Once the incorrect timetag was noticed, the real S/C load was retrieved from the backup string and uplinked to the spacecraft.	4/6/1999	Closed
98	4/2/1999	WSC Forward Link Equipment Failover	4 minute 19 second late acq. WSC had to do a Forward Link Equipment Failover to recover. TTR#20731.	4/6/1999	Closed
99	4/5/1999	NASCOM WAN/LAN Router Upgrade Caused I&Q Channel Dropout	On DOY 095 in the 1106z TDW/SSA1 event, NASCOM was performing a WAN/LAN IP router transition upgrade which unexpectedly caused the I&Q channels to dropout from 11:09:57 to 11:12:08 and 11:15:58 through the remainder of the event.	6/24/1999	Closed
100	4/12/1999	TR1XT1 Hard Crash During Real-time Event	TR1XT1 crashed @1230z crippling event logging causing no response from state manager on all workstations and xterms on primary string. Unable to recover xterminal even after recycling software, workstation shutdown and a hard reboot.	6/24/1999	Closed
101	4/12/1999	Poor Data Quality during TDW Events	During the 17:12 and 18:50 TDW Events we saw numerous sequence errors on both the I and Q channels (NASCOM Frame level). TTR # 20752	6/24/1999	Closed
102	5/11/1999	Missed PR Calibration Request	The PR External Calibration request which was sent to the MOC via TSDIS was not scheduled because it was missed. The MP had an e-mail filter in place and did not see the message, and the other engineers forgot to verify that the request was in the load.	6/24/1999	Closed

#	Date Opened	Title	Description	Date Closed	Status
103	5/21/1999	Late Acquisition	Pass scheduled to begin @ 19:00:00z, did not acquire until 19:03:09 (2 minutes and 39 seconds late). Sent FWD Reacq 1 minute into scheduled beginning of the pass and still did not acquire. Verified correct TDRSS and RTS was used.	6/24/1999	Closed
104	6/1/1999	Front End Processor #1 DC Card Disconnect	During the 15:20:04 - 15:33:00 event on day 152 the DC card on the Front End processor failed to work properly. All telemetry became frozen, noticed a red light on CH#1 overflow of the Front End Processor being laminated.	6/24/1999	Closed
105	6/18/1999	Loss of Signal Due to Weather Problem at White Sands	During 044330z event the MOC lost telemetry at 044945z. MOC personnel reported the dropout to CSC-1. CSC-1 explained that there was a weather problem at White Sands causing a weak signal level from TDRS. No GCMRs were sent.	6/24/1999	Closed
106	6/30/1999	Unable to reacquire after performing COHO switch	Unable to reacquire after executing RTS 69 (@09:44:06) for COHO switch. Reacquired 50 seconds later, on Q-Channel, and I -Channel locked up briefly before dropping out.	8/2/1999	Closed

Appendix C: Late Acquisition Reports

#	Date Opened	Title	Description	Date Closed	Status
1	12/24/1997	Late Acquisition	1 minute 38 seconds of late acquisition during the 358/1743z event. No data was lost, all VCDU's were recovered. TTR#: 19639	9/11/1998	Closed
2	1/13/1998	Late Acquisition	1 minute 37 second late acquisition during 017/1749 TDW SSA2 event. No impact. Generic TTR # 19639.	9/11/1998	Closed
3	1/26/1998	Late Acquisition	Late acquisition for event scheduled at 110030z. Signal was acquired at 110130z. Generic TTR#19639 1 minute 32k data loss - recoverable	9/11/1998	Closed
4	2/6/1998	Late Acquisition	Late acquisition for event scheduled @ 143847z. Signal was acquired @ 144029z. Generic TTR# 19639. 1 min 12 sec 32k data loss - recoverable.	9/11/1998	Closed
5	3/9/1998	Late Acquisition	Lost lock on I channel at AOS. 1min. 57sec of I channel data (32Kbps) was affected but it's recoverable. TTR# 19639 was written for the event. Next TDRS event experienced no problem with I channel data.	9/11/1998	Closed
6	3/14/1998	Late Acquisition	MOC failed to acquire at AOS during event scheduled for 0953z. A GCMR was sent for forward reacquisition at 0954z and the MOC locked on data at 0955z. TTR# 19639 (generic) was assigned to this case. Approx. 1 min 40 sec. 32kbps data loss - recoverable.	9/11/1998	Closed
7	4/3/1998	Late Acquisition	Did not acquire at scheduled AOS (09:06), sent a GCMR: FWD REAC and locked up 2 minutes into the event (09:08 AOS). Received data in time for playback but missed event buffer dump. CSC 2 assigned TTR # 19639 to the discrepancy.	9/11/1998	Closed
8	4/14/1998	Late Acquisition	Late acquisition for event scheduled at 001200z. Signal was acquired at 001350z. Generic TTR#19639 1minute 20 seconds 32k data loss - recoverable	9/11/1998	Closed
9	5/10/1998	Late Acquisition	Late acquisition for event scheduled at 061100z. Signal was acquired at 061252z. Generic TTR#19639 1minute 22 seconds 32k data loss - recoverable.	9/11/1998	Closed
10	6/18/1998	Late Acquisition	1 minute 4 seconds of late acquisition during the 0054z event. No data was lost, all VCDUs were recovered. TTR#: 19639	9/11/1998	Closed
11	7/7/1998	Late Acquisition	1 minute 35 seconds of late acquisition during the 188/1347z event. No data was lost, all VCDUs were recovered. TTR#: 19639	9/11/1998	Closed

#	Date Opened	Title	Description	Date Closed	Status
12	7/8/1998	Late Acquisition	1 minute 21 seconds of late acquisition during the 189/0035z event. No data was lost, all VCDUs were recovered. TTR#: 19639	9/11/1998	Closed
13	7/12/1998	Late Acquisition	Generic late acquisition at the 0348 support TTR #19639 Locked up on data at 193/035032	9/11/1998	Closed
14	7/22/1998	Late Acquisition	1 minute 12 seconds of late acquisition during the 0934z event. No data was lost, all VCDUs were recovered. TTR#: 19639	9/11/1998	Closed
15	7/22/1998	Late Acquisition	52 second late acquisition during the 1743z event. No data was lost, all VCDUs were recovered. No Forward reacquisition GCMR was sent - TTR#: 19639.	9/11/1998	Closed
16	8/31/1998	Late Acquisition	1 minute late acquisition during the 00:46z event. No data was lost, all VCDUs were recovered. A Forward reacquisition GCMR was sent .	9/11/1998	Closed
17	9/5/1998	Late Acquisition	Late acquisition at the 0346 TDW support. 1 min 18 secs 32k data loss -- recoverable Generic TTR# 19639	9/11/1998	Closed
18	9/15/1998	Late Acquisition	Late acquisition during the 0317z TDW support. 1 min 23 secs 32k of data loss -- recoverable Generic TTR# 19639	10/1/1998	Closed
19	9/17/1998	Late Acquisition	Late acquisition during the 1328z TDW support. 1 min 58 secs 32k data loss -- recoverable. Generic TTR# 19639	10/1/1998	Closed
20	9/23/1998	Late Acquisition	Late acquisition during the 1144z TDE support. 1 min 23 secs 32k data loss -- recoverable. Generic TTR# 19639	10/1/1998	Closed
21	9/25/1998	Late Acquisition	Late acquisition during the 1547z TDE support. 1 min 32 secs 32k data loss -- recoverable. Generic TTR# 19639	10/1/1998	Closed
22	10/6/1998	Late Acquisition	Late acquisition during the 0032z TDW support. 1 min 39 secs 32k data loss -- recoverable. Generic TTR# 19639	10/1/1998	Closed
23	10/22/1998	Late Acquisition	Late acquisition during the 082521z TDW support. 1 min 29 secs 32k data loss -- recoverable. Generic TTR# 19639	10/22/1998	Closed
24	10/26/1998	Late Acquisition	Late acquisition during the 2331z TDE support. 2 min 26 secs 32k data loss -- recoverable. Generic TTR# 19639	1/12/1999	Closed
25	11/13/1998	Late Acquisition	Late acquisition during the 0421z 171 support. 1 min 7 secs 32k data loss -- recoverable. Generic TTR# 19639.	1/12/1999	Closed
26	1/11/1999	Late Acquisition	Generic Late Acquisition during the 234630/TDW event. 1 min 6 secs 32k data loss -- recoverable. TTR# 19639.	1/12/1999	Closed
27	2/17/1999	Late Acquisition	Generic Late Acquisition during the 234630/TDW event. 1 min 6 secs 32k data loss -- recoverable. TTR# 19639.	1/12/1999	Closed

#	Date Opened	Title	Description	Date Closed	Status
28	3/8/1999	Late Acquisition	Generic Late Acquisition during the 221400/TDW event. 1 min 28 secs 32k data loss -- recoverable. TTR# 19639.	4/6/1999	Closed
29	3/31/1999	Late Acquisition	A Generic Late Acquisition during the 0726 event . 1 min. and 27 secs. 32K data loss recoverable. TTR# 19639.	4/6/1999	Closed
30	4/3/1999	Late Acquisition	A Generic Late Acquisition during the 2139 event . 1 min. and 04 secs. 32K data loss recoverable. TTR# 19639.	4/6/1999	Closed
31	4/5/1999	Late Acquisition	A Generic Late Acquisition during the 0928 event . 52 Second 32K data loss recoverable. TTR# 19639.	4/6/1999	Closed
32	5/12/1999	Late Acquisition	TRMM had a 1 minute 14 seconds of late acquisition during the 132/0825z event. No data was lost, all VCDUs were recovered. TTR#: 19639	6/30/1999	Closed
33	5/20/1999	Late Acquisition	1 minute and 19 second Late Acq. TTR #19639 All Data Recovered.	6/30/1999	Closed

Appendix D: Configuration Change Requests

#	Date Opened	Title	Description	Status
CCR-001	11/28/1997	S/C RTS #3 (Safehold) Disables Wrong TSM	RTS #3 (in EEPROM) disables TSMs #18 and #20. It is supposed to disable TSM's #19 & #20 (Transmitter-B on-time monitors) since, the RTS switches to Transmitter-B.	Approved - Implemented
CCR-002	11/30/1997	TAM Static FDC Tolerance Too Wide	The default TAM Static FDC tolerance is set too wide due to an unexpected low level of noise on TAM A and B.	Approved - Implemented
CCR-003	11/30/1997	ACS S/W Use of HW Eclipse Transition Deadband	The ACS Software is currently using the NITE2DAY deadband for transition to Night and the DAY2NITE deadband for transitions to Day (in ACCSS.C).	Open
CCR-004	12/11/1997	Update DSS & ESA Params Based on FDF Calibration	Update following tables based on FDF calibration data: Table 65 - DSS-2 alignment Table 59 - ESA penetration biases Table 82 - Yaw update parameters (lower KYaw)	Approved - Implemented
CCR-005	12/11/1997	Correct Epoch of ACS Magnetic Field Model	The as-launch ACS flight software contains the magnetic field model coefficients for the 1995-epoched magnetic field model; however, an epoch of 1990 is hardcoded into the ACS software.	Approved - Testing
CCR-006	12/13/1997	Update Scale Factor For Primary Z Axis Gyro	Update scale factor for primary Z axis gyro based on FDF calibration data (from 180 degree yaw maneuver).	Approved - Implemented
CCR-007	12/4/1997	TSM to Detect SPRU Trans to CM Mode	Develop an on-board TSM monitor to detect the transition (in PSIB telemetry) to Constant Current mode. This monitor should look for the IA bit to become zero. At this point an RTS will be activated to collect FAST telemetry from the PSIB.	Rejected
CCR-008	12/11/1997	Update ACS S/W to Handle Non-Orthogonal DSS	The table 65 update made as part of CCR-004 corrected for the non-orthogonality of the heads on DSS-2; however, consideration for a long term software change should be made.	Open
CCR-009	12/29/1997	Record Contingency Mode Packets in Data Storage	The current data storage filter table (#68) filters out contingency mode packets. Update this table to allow all contingency mode packets requested to be stored.	Approved - Implemented
CCR-010	12/30/1997	Gyro Analog/Digital Comparison Failure Threshold Low	FDS Test #0 failed its first threshold causing a switch to the redundant x-axis gyro.	Approved - Implemented

#	Date Opened	Title	Description	Status
CCR-011	1/12/1998	Change VIRS Day/Night Telemetry Monitor	Current VIRS Day/Night mode monitors (#29 & 30) evaluate the PSIB Time in Night telemetry point. Due to a recent anomaly where the PSIB detected night intermittently during the day, this monitor failed causing a loss of VIRS science	Approved - Implemented
CCR-012	1/12/1998	Kalman Filter Parameter Changes for Contingency Mode	Parameters need to be adjusted for contingency mode. Three versions of these parameters are needed during the contingency mode test. One primary and two backups.	Approved - Implemented
CCR-013	1/28/1998	Memory Dwell for TC Flywheel Anomaly Investigation	To see certain data associated with the investigation of the TC Flywheel anomaly at a faster rate, it is necessary to load memory dwell tables 002 and 003 and enable memory dwell.	Approved - Implemented
CCR-014	1/29/1998	Delta-V Body Momentum Y-Axis Limit Too Tight	The Delta-V maneuver on Day 24 aborted due to the Y-axis system momentum exceeding 30 Nms. It was determined that this system momentum is nominal and that the limit that failed causing the abort needs to be widened from 30 Nms to 40 Nms.	Approved - Implemented
CCR-015	2/17/1998	Record Contingency Mode Packets in Data Storage ACE-B	Table 69 must be changed to record contingency mode packets. This change was made for ACE-A (see CCR-009). ACE-B needs to be updated.	Approved - Implemented
CCR-016	2/6/1998	Solar Array Cha-Cha	When the ACS switches from 3 to 4 ESA head control, a position error is introduced into the system causing the solar arrays to “bang” back and forth.	Approved - Implemented
CCR-017	2/24/1998	TDRS Continuity Changes	ACS Table 86 needs to reflect the addition of TDRS West BU (TDRS4). Due to the Delta-V failure, the continuity limit check failed. ACS Table 85 needs to increase the distance for its position continuity check limit.	Approved - Implemented
CCR-018	2/25/1998	DSS Improvements for Yaw Update	FDF calculated new DSS coefficients to improve Yaw updates. These valves have been tested by ACS. The now values are modified in ACS Tables 64 and 65.	Approved - Implemented
CCR-019	2/27/1998	IRU Updates_	FDF has supplied new IRU data for calibration. ACS Tables 55 and 56 need to be updated.	Approved - Implemented
CCR-020	3/5/1998	Delta-V Momentum Limit Extended	Burn 136 hit ~38 Nms on its first peak. The limit of 40 Nms should be increased to 45 Nms.	Approved - Implemented
CCR-021	3/6/1998	TDRS Position and Velocity Changes	TDRS West ephemeris from FDF does not work well. TDRS continuity and velocity checks failed.	Approved - Implemented

#	Date Opened	Title	Description	Status
CCR-022	3/31/1998	FDF Redundant IRU Calibration	FDF has calculated new redundant IRU calibrations to load to the S/C.	Approved - Implemented
CCR-023	3/31/1998	DS Quota Table for VIRS - day mode	Since VIRS will be in day mode at all times, it will require more virtual recorder space.	Approved - Implemented
CCR-024	5/8/1998	Modify TRMM Loadshed RTS (RTS#2)	Current LOADSHED RTS (called for Low Power and Safehold) commands the SPRU to Peak Power Tracking mode. This is no longer desirable due to the problem with Battery 2 - Cell 1.	Approved - Implemented
CCR-025	5/8/1998	Decreased TRMM Solar Array Range of Motion	Due to high temperatures on the -Y Solar Array actuator, the deployables engineer wishes to decrease the motion on the Solar Array as much as possible. Also, keeping the arrays closer to "feathered" decreases drag and increases mission life.	Approved - Implemented
CCR-026	6/8/1998	Combination Redundant IRU Calibrations	FDF has calculated new values for the combinations of redundant and primary IRU's. Updated tables should be made available for the S/C in case of an IRU failure.	Approved - Testing
CCR-027	6/8/1998	Contingency Mode DSS Calibrations	FDF has calculated new values for the DSS to be used if the S/C enters contingency mode.	Approved - Testing
CCR-028	6/8/1998	TAM Calibrations	FDF has calculated the TAM calibrations to be used on the S/C.	Approved - Implemented
CCR-029	6/16/1998	Data Storage Task Backup Flaw	A flaw in the Data Storage task backup segment mechanism may place the spacecraft processor into a state where it cannot be recovered into normal mode.	Rejected
CCR-030	6/18/1998	ESA Interference FDC	On April 24, 1998 (DOY #115), TRMM entered Sun Acquisition Mode as a result of ESA FDC. The ESA interference periods predicted by the on-board software exceeded the ten minute time limit, tripping FDC #81 and #83.	Approved - Implemented
CCR-031	6/25/1998	New EOD BSOC Monitors	Loadshed Anomaly occurred due to PSIB misconfiguration. The SPRU got stuck in trickle charge long enough to run the batteries to below 70% SOC. See Anomaly Report #59.	Approved - Implemented
CCR-032	8/5/1998	Addition of GSACE Look at ACE command to RTS #6	Currently, if TSMs 10 or 11 are triggered (ACE B In Control Flag), RTS 6 or 7 gets triggered, respectively. RTS 6 Disables ACEA SH monitoring, and enables ACEB SH monitoring, since it is now ACE In Control.	Rejected

#	Date Opened	Title	Description	Status
CCR-033	8/5/1998	Abort ACS ATS if BURN1 is Rejected but not aborted	If burn 1 of a maneuver is rejected, the ACS ATS still executes and burn 2 could still go off with an invalid EPV, eventually putting the spacecraft in safehold.	Open
CCR-034	8/11/1998	Write RAM Tables to EEPROM	There are tables that have been written only to RAM on-board the spacecraft. In the event of a cold start, they would have to be reloaded to RAM. The absence of some of these tables in RAM as a result of the cold start could cause adverse affects.	Approved - Testing
CCR-035	8/24/1998	Modify ACS System Table 85 - Widen TDRS Continuity	The TRMM MOC only uplinks TDRS vectors once a month. Based on the two different methods which FDF uses to generate these vectors, these vectors sometimes fail the current 400 km continuity check upon uplink.	Approved - Implemented
CCR-036	9/11/1998	CERES DAA+15V Voltage Monitor	Starting 98- 212 (July 31), the CERES DAA+15V voltage converter began increasing voltage. On 98-230, the voltage converter hit YH limits. After a few operational changes to reduce the temperature and voltage of the converter, the instrument was powered OFF.	Approved - Implemented
CCR-037	10/2/1998	TRMM Fuel Mass Update	The spacecraft mass value that is defined in ACS System Table #84 should be updated once a year based on fuel consumption estimates for optimal performance.	Approved - Implemented
CCR-038	1/13/1999	Solar Array Software Stop Dwell Table Loads	TRMM's 50° Solar Array Software Stops contributed to a SUNACQ transition on 1999/0103. In order to safely toggle between 50° and 130° SA Stops, the FOT needs a quick way to determine which value is on the spacecraft.	Approved - Implemented
CCR-039	1/14/1999	Eliminate all TSMs that were used only for launch	As an added precaution, it would be a good idea to null out all Launch S/C TSMs that will no longer ever be used, such as S/C Separation Monitor, Deployment Monitors, etc. and make them into spares again. The Monitor Numbers are #44 through #63.	Approved - Testing
CCR-040	3/3/1999	ESA Interference FDC - Change #2	Recent FDF predictions showed that sun/moon interference in the ESA quadrants would last longer than the current FDC time limit of 13.3 minutes (1600 consecutive samples).	Approved - Implemented

#	Date Opened	Title	Description	Status
CCR-041	3/25/1999	HDS Solar Model Bug	In the ESA Sun/Moon extended-interference test case (02/16/99) in the STTF, we have been seeing the spacecraft go to Sun Acq in the first orbit, after the 2nd Yaw Update attempt.	Approved - Implemented
CCR-042	4/6/1999	Magnetic Torquer Bar Limits Change	If the -Y solar array is stopped in a fixed position, intentionally or due to failure, the resulting aerodynamic torque (due to different -Y and +Y positions) require a change in magnetic torquer bar parameters for stable momentum management.	Approved - Testing
CCR-043	4/7/1999	Widen The SA Sensed vs. Cmded FDC Tolerance	A delta-v maneuver was performed near the afternoon 50-degree solar array software stops. The maneuver completed, the arrays slewed, and, then, started tracking. At this point, the arrays were about 2 degrees away from the commanded position.	Approved - Implemented
CCR-044	4/6/1999	SA Commanded VS. Sensed Positions TSMs	Since the FDC's that check the commanded versus sensed solar array positions have had their limits changed from 0.5 degrees to 12 degrees, it is desirable to have TSMs monitor this value for each array on each GSACE.	Approved - Implemented
CCR-045	4/13/1999	CERES Removal From Sun Acq/ Safehold	This is based on a request from the LaRC CERES instrument team that CERES be removed from load-shed. The CERES instrument has a failing voltage converter. When the converter fails regulating current, the electronics can operate.	Approved - Testing
CCR-046	5/5/1999	ACS System Table 76 Update for Stopped Solar Array	In order to test and ultimately stop the TRMM -Y Solar Array at +30°, ACS System Table 76 must be modified to have the arrays feather at 30°, and to return the full range of travel to 130°, instead of 50°.	Approved - Closed
CCR-047	6/2/1999	Frequency Standard Contingency Testing	The members of the FSW Maintenance Team shall track the development effort of the frequency standard contingency by attending reviews through the initial testing phase.	Approved - Testing
CCR-048	6/21/1999	Create new DS Filter Table for TRMM	Currently, if it is desired to look at 8-hz ACS data for contingency purposes, a new table 68 (DS Filter Table 1) needs to be uplinked. This process takes time and introduces risk.	Approved - Testing
CCR-049	5/21/1999	PSIB Orbit Status Information Not Updating	The PSIB Orbit Status parameters are not updating in telemetry. The power subsystem continues to operate nominally.	Approved - Implemented

#	Date Opened	Title	Description	Status
CCR-050	6/21/1999	Change PSIB Timer Comparison Logic	There is timer comparison logic in the PSIB software that does not account for roll-over situations.	Approved - Testing
CCR-051	6/15/1999	MTB Cmded Vs Sensed Dipole Moment	The spacecraft began experiencing abnormal vibrations every orbit noon just before the maximum beta angle. These attitude errors were fed into the MTB control loop causing the vibrations to be accentuated. FDC #9 fired, switching MTB commanding to 100%.	Approved - Implemented
CCR-052	7/20/1999	Command Solar Array Sun-Tracking with Nominal Attitude	The spacecraft began experiencing abnormal vibrations every orbit noon just before the maximum beta angle. See CCR-051. Analysis by the ACS engineers indicates that this is correlated to a mechanical resonance mode of the spacecraft/solar array assembly.	Approved - Testing

Appendix E: Table Load List

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
ACS	10	X	ACS Abort Thruster RTS (FDC)	This RTS only resides in RAM (no EEPROM version).	11/27/1997		Loaded on Launch Pad.
ACS	11	X	ACS ACE-B Safehold RTS (FDC)	This RTS only resides in RAM (no EEPROM version).	11/27/1997		Loaded on Launch Pad.
ACS	12	X	ACS ACE-A Safehold RTS (FDC)	This RTS only resides in RAM (no EEPROM version).	11/27/1997		Loaded on Launch Pad.
ACS	14	X	ACES to TAMB RTS (FDC)	This RTS only resides in RAM (no EEPROM version).	11/27/1997		Loaded on Launch Pad.
ACS	16	X	CSS-B and ACE-B Safehold RTS (FDC)	This RTS only resides in RAM (no EEPROM version).	11/27/1997		Loaded on Launch Pad.
ACS	53		FDC Statistics Table	Permanent modification to Delta-H Mode FDC limits (see PTR-1910 and SCCR #153).	11/27/1997		Loaded on Launch Pad.
ACS	81	X	Control Law Parameter Limits	Permanent modification to Delta-H Mode FDC limits (see PTR-1910 and SCCR #153).	11/27/1997	11/12/1998	Loaded on Launch Pad.
ACS	10 6		FDC Test Table	Selected FDC's are disabled at launch.	11/27/1997		Loaded on Launch Pad. FDC's were all re-enabled in post-launch activities (via ground command.)
SC	68		DS filter table 1	Modified to record ALL 8Hz ACE-A data	11/27/1997 06/15/1999		Loaded on Launch Pad. Loaded to gather data on MTB cmd vs. sensed FDC's 9, 12 & 13, 14
SC	69		DS filter table 2	Modified to record ALL 8Hz ACE-B data.	11/27/1997		Loaded on Launch Pad.
SC	68		DS filter table 1	Returned to default (EEPROM) version.	11/28/1997		After Santiago Playback. 97-332-00:09
SC	69		DS filter table 2	Returned to default (EEPROM) version.	11/28/1997		After Santiago Playback. 97-332-00:11
ACS	86		Ephemeris Parameters	Disable TRMM Continuity Check (TRMM, TDRS East, TDRS West and TDRS East BU enabled).	11/28/1997		Loaded prior to second TRMM ephemeris update (based on FDF tracking data).

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
ACS	86		Ephemeris Parameters	Enable TRMM Continuity Check (TRMM, TDRS East, TDRS West and TDRS East BU enabled).	11/28/1997		Loaded after confirmation of tracking data based ephem.
ACS	10 2		FDC Mode check table	Update for contingency per ACS User's Guide.	11/28/1997		At start of "contingency" test.
ACS	90		ACS Mode config table	Update for contingency per ACS User's Guide.	11/28/1997		At start of "contingency" test.
ACS	81		Control Law Parameter Limits	Update for contingency per ACS User's Guide.	11/28/1998		At start of "contingency" test.
ACS	80		Control Law Gains	Update for contingency per ACS User's Guide.	11/28/1997		At start of "contingency" test.
ACS	10 2		FDC Mode check table	Reset to default (EEPROM) version.	11/28/1997		At end of "contingency" test.
ACS	90		ACS Mode config table	Reset to default (EEPROM) version.	11/28/1997		At end of "contingency" test.
ACS	81		Control Law Parameter Limits	Reset to default (loaded pre-launch) version.	11/28/1997		At end of "contingency" test.
ACS	80		Control Law Gains	Reset to default (EEPROM) version.	11/28/1997		At end of "contingency" test.
SC	3	X	Safehold RTS (ACE)	Modified to disable correct Transmitter TSM's.	11/28/1997		Prior to entering ACS Nominal Mode.
SC	73	X	Flight Recorder Quota Table	Quota table for normal operation with TRMM instruments (approx 215 min / instrument).	11/29/1997		Start of instrument science data collection. 97-333-13:33
ACS	73		ACS Delta-v Parameters	Increase MAX Burn time to 180 seconds.	12/5/1997		Loaded prior to start of Descent burns.
ACS	73		ACS Delta-v Parameters	Return MAX Burn time to 60 seconds.	12/14/1997		Reloaded (default) after completion of Descent burns.
SC	7		ACE-B 1kbps RTS	Reload version that is in EEPROM (different from launch version).	12/1/1997		Reload version in EEPROM (return to default).
ACS	57	X	TAM Parameters	Decrease threshold for TAM static data check (Post launch SCCR #2)	12/1/1997		Loaded on 97-335.
ACS	61	X	CSS Parameters	Reversed NITE2DAY and DAY2NITE deadband parameters.	12/1/1997	11/12/1998	Loaded on 97-335.
ACS	65	X	DSS Alignments	Updated DSS-2 Alignment matrix based on FDF Calibration.	12/12/1997		Loaded on 97-346 at approx 14:30.
ACS	59		ESA Parameters	Updated ESA Penetration biases based on FDF Calibration (parameters in wrong order).	12/12/1997		Loaded on 97-346 at approx 14:30.

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
ACS	59	X	ESA Parameters	Updated ESA Penetration biases based on FDF Calibration (parameters in correct order).	12/12/1997	11/12/1998	Loaded on 97-346 at approx 19:30.
ACS	82	X	Yaw Update Parameters	Change KYaw from 0.75 to 0.2	12/12/1997	11/12/1998	Loaded on 97-346 at 22:42.
ACS	87		Magnetic Field Model Parameters	Changed back to coefficients from "1990" model until Epoch in code can be changed to 1995.	12/13/1997		Loaded on 97-347 at 01:52.
ACS	55		Gyro Parameters	Updated primary Z axis gyro scale factor based on FDF Calibration (incorrect value).	12/13/1997		Loaded on 97-347 at 17:10
ACS	55		Gyro Parameters	Updated primary Z axis gyro scale factor based on FDF Calibration (correct value).	12/14/1997		Loaded on 97-348 at 15:59
SC	68	X	DS Filter Table 1	Enable recording of Contingency Mode Packets	12/29/1997 06/15/1999	11/13/1998	Reloaded from EEPROM to RAM on 06/15/99
ACS	53	X	FDC Statistics Table	Change gyro analog to digital rate FDC to require 10 cycles (instead of 5) before switching to redundant IRU.	12/30/1997		Result of FDC that tripped due to "rates" instilled by S/A motion due to switch from 3 to 4 ESA heads.
SC	33	X	VIRS NIGHT RTS	Modified in conjunction with updates to VIRS Day/Night TSM changes.	2/8/1998		
SC	21	X	Update to TSM's #29 & #30	Changed VIRS Day/Night cycling to be based on PSIB Day/Night Flag - not PSIB Time In Nite.	2/8/1998		
ACS	51	X	Kalman Filter Parameters	Updated parameters prior to contingency mode test.	1/12/1998	11/12/1998	
ACS	102		FDC Mode check table	Update for contingency per ACS User's Guide.	1/13/1998		At start of "contingency" test.
ACS	90		ACS Mode config table	Update for contingency per ACS User's Guide.	1/13/1998		At start of "contingency" test.
ACS	81		Control Law Parameter Limits	Update for contingency per ACS User's Guide.	1/13/1998		At start of "contingency" test.
ACS	80		Control Law Gains	Update for contingency per ACS User's Guide.	1/13/1998		At start of "contingency" test.
ACS	102		FDC Mode check table	Reset to default (EEPROM) version.	1/13/1998		At end of "contingency" test.
ACS	90		ACS Mode config table	Reset to default (EEPROM) version.	1/13/1998		At end of "contingency" test.
ACS	81		Control Law Parameter Limits	Reset to default (loaded pre-launch) version.	1/13/1998		At end of "contingency" test.

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
ACS	80		Control Law Gains	Reset to default (EEPROM) version.	1/13/1998		At end of "contingency" test.
ACS	82		Yaw Update Parameters	Increase "acceptance" threshold for Yaw Updates.	1/13/1998		This load was needed after the contingency mode test.
ACS	82		Yaw Update Parameters	Change KYaw from 0.75 to 0.2	1/13/1998		Restored table loaded on 97-346 after yaw update was successfully performed.
ACS	73		Delta-v Parameters	Increased Yaw axis FDC momentum limit from 30 to 40.	1/25/1998		Result of FDC that tripped during causing aborted Delta-v.
ACS	86		Ephemeris Parameters	Disable TRMM Continuity Check (TRMM, TDRS East, TDRS West and TDRS East BU enabled).	1/25/1998		Loaded on 1998-025 in order to allow acceptance of FDF ephem after aborted delta-v.
ACS	86		Ephemeris Parameters	Enable TRMM Continuity Check (TRMM, TDRS East, TDRS West and TDRS East BU enabled).	1/25/1998		Loaded on 1998-025 after FDF ephem was successfully loaded.
SC	2	X	Memory Dwell Addresses	Troubleshoot flywheel anomaly.	1/28/1998		
SC	3	X	Memory Dwell Delay	Troubleshoot flywheel anomaly.	1/28/1998		
ACS	83	X	First Order Filter Coefficients	Disable filtering of ESA S-counts.	2/6/1998	11/12/1998	Turns of ESA S-count filtering to alleviate "spikes" in position error on switching from 3 head to 4 head ESA processing.
ACS	86		Ephemeris Parameters	Enable TRMM Continuity Check Disabled. TDRS West BU Propagation Enabled.	2/24/1998		Modified after TDRS West BU was found to be disabled.
ACS	86		Ephemeris Parameters	Enable TRMM Continuity Check Enabled. TDRS West BU Propagation Enabled.	2/24/1998		Modified after TDRS West BU was found to be disabled.
ACS	85		Ephemeris Limits	Changed Position Continuity Check Limit to 300 km.	2/24/1998		

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
SC	69	X	DS Filter Table 2	Enable recording of Contingency Mode Packets	2/18/1998	11/13/1998	
ACS	64	X	DSS Parameter Data	Changed to improve yaw updates based on FDF calculations.	2/25/1998	11/12/1998	
ACS	65	X	DSS Alignments	Changed to improve yaw updates based on FDF calculations.	2/25/1998	11/12/1998	
ACS	55	X	Gyro Parameters	Updated primary gyro drift biases based on FDF calibrations.	2/27/1998		
ACS	56	X	Gyro-To-Body Transformation Matrix	Updated new "scaled" misalignment matrix from FDF.	2/27/1998	11/12/1998	
ACS	73	X	Delta-v Parameters	Increased Delta-V Y axis momentum limit from 40 to 45.	3/5/1998	11/12/1998	ACS saw the value reach 38 last time. They wanted more breathing room.
ACS	85		Ephemeris Limits	Changed position continuity check from 400 to 2400 and velocity continuity check from 0.03 to 0.18 on both TDRS W and Wbu.	3/6/1998		
ACS	55	X	Gyro Parameters	Updated redundant gyro drift biases based on FDF calibrations.	4/14/1998	11/12/1998	
SC	73	X	DS Quota Table	Allocated more space to the VIRS VR	4/7/1998		
ACS	76		Solar Array Parameters	Software stops changed to ±50 degrees in order to reduce drag and solar array motion.	5/26/98 6/10/98 12/15/98	12/16/1998	Loaded for SA Motor patch.
ACS	76		Solar Array Parameters	Software stops changed to ±70 degrees.	N/A		This table is to be loaded in case the ±50 s/w stops fail to collect enough power.
ACS	58	X	TAM transformation matrices	FDF calibrations	7/9/1998	11/12/1998	
ACS	57	X	TAM biases	FDF calibrations	7/9/1998	11/12/1998	
ACS	67	X	MTB contamination matrix	FDF calibrations	7/9/1998	11/12/1998	
SC	2	X	Loadshed RTS	Put power sys config in RTS 13	6/11/1998		

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
SC	13	X	SPRU Config RTS	Configure the power sys to CM_2, Gain 1, V/T Level 5	6/11/1998		
SC	21		New TSM's #31, #32, #33, & #34	Monitor Batteries 1 & 2 end-of-day BSOC, for PSIB A/B	6/30/1998		
ACS	53		FDC Statistics Table	Increased sun/moon interference values to 13.3 minutes from 10 minutes.	7/9/1998	11/12/1998	
ACS	87	X	Magnetic Field Model Parameters	Changed back to coefficients from "1995" model after Epoch in code was be changed to 1995.	9/10/1998		
SC	21	X	New TSM's #35, #36, & #37	Monitor CERES DAA +15 voltage with the long wave bridge balance	9/17/1998		
SC	21	X	TSM Threshold Table	Increase of Red Upper Limit from +16.3 to 17.963V for TSM #36 Threshold #0	10/13/1998		
ACS	2		Dwell Table	for SA EEPROM Patch			
ACS	3		Dwell Table	for SA EEPROM Patch			
ACS	2		Dwell Table	for SA RAM Patch			
ACS	3		Dwell Table	for SA RAM Patch			
ACS	76		Solar Array Parameters	Launch version of table			
ACS	76		Solar Array Parameters	Launch version of table			
ACS	2		Dwell Table	Dwell 0-3 for SA min/max stops	1/12/1999		
ACS	3		Dwell Delay Table	Dwell 0-3 for SA min/max stops	1/14/1999		
ACS	76	X	Solar Array Parameters	+/-50 deg stops and 12-deg FDC tolerance for cmd vs sensed SA	2/9/1999		
ACS	21		TS limit table	Add monitor 2-13 for SA sensed vs. commanded position	2/17/1999		
ACS	85		Ephemeris Limits	Changed TDRS Position Continuity Check Limit to 800 km.	3/1/1999		Increased TDRS Position Limits 400-800 km - next TDRS ephem update failed position and velocity cont. check - #85 was copied from EEPROM to RAM on DOY 68 (3/9/99)

Proc	#	Perm	Description	Reason	Date Loaded to RAM	Date Loaded to EEPROM	Comments
ACS	54		System Parameters	Torquer bat changes for a stuck solar array			Prepared for use in case -Y SA gets stuck
ACS	66		MTB Parameters	Torquer bar changes for a stuck solar array			Prepared for use in case -Y SA gets stuck
ACS	53		FDC Statistics Table	Increased sun/moon interference values to 16 minutes from 13.3 minutes.	4/6/1999		
ACS	84	X	Ephemeris Model Coefficient Table	Update s/c mass to 3368 kg	5/4/1999		
ACS	66		MTB Parameters	Change MTB cmd vs. sensed tolerance from 40 to 200 Am2			ACS folks decided not use this table update; updated table 53 instead
ACS	53	X	FDC Statistics Table	Increased MTB cmded vs. sensed out-of-tolerance time limit to 5 min.	6/15/1999		

Appendix F: Supporting Figures and Tables

Flight Operations

Time of Data Loss	Recorder Overflow	VR ID	Reason
98/026/03:58:32 - 026/03:59:30	Yes	5	FOT did not support previous event; Event #9
98/026/04:00:17 - 026/04:02:39	Yes	6	FOT did not support previous event; Event #9
98/062/21:30:47 - 063/01:43:43	No	2	Low Power; Anomaly #59
98/062/21:30:47 - 063/01:06:26	No	3	Low Power; Anomaly #59
98/062/21:30:47 - 063/00:22:51	No	4	Low Power; Anomaly #59
98/062/21:30:47 - 062/23:34:26	No	5	Low Power; Anomaly #59
98/062/21:30:47 - 063/00:55:40	No	6	Low Power; Anomaly #59
98/065/15:53:41 - 065/15:53:49	No	4	Missing PR packets from TO; Anomaly #61
98/065/15:54:27 - 065/15:54:35	No	4	Missing PR packets from TO; Anomaly #61
98/101/00:00:04 - 101/02:34:29	No	2	Safing command in ATS; Event #25
98/112/21:16:32 - 112/21:17:45	No	3	Retransmit failed on prime string; Event #29
98/113/00:01:11 - 113/01:57:53	No	2	CERES safed self due to seeing Sun; Event #30
98/115/03:15:30 - 115/14:32:21	No	2	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/115/03:15:30 - 115/09:18:49	No	3	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/115/03:15:30 - 115/11:20:03	No	4	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/115/03:15:30 - 115/09:12:21	No	5	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/115/03:15:30 - 116/21:03:58	No	6	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/115/06:21:09 - 115/07:50:07	Yes	1	Sun Acq due to FDC violation; Event #31 and Anomaly #67
98/116/06:46:45 - 116/07:00:02	Yes	4	Mutual Interference; Event #32
98/160/15:35:22 - 160/15:38:39	Yes	2	TDS event taken by NCC; Event #39
98/160/15:33:03 - 160/15:38:39	Yes	3	TDS event taken by NCC; Event #39
98/160/15:35:13 - 160/15:38:33	Yes	4	TDS event taken by NCC; Event #39
98/160/15:35:18 - 160/15:38:39	Yes	5	TDS event taken by NCC; Event #39
98/160/15:35:19 - 160/15:38:39	Yes	6	TDS event taken by NCC; Event #39
98/172/00:00:04 - 172/03:36:05	Yes	2	Daily ATS load not uplinked, safing RTS executed; Event #41
98/172/02:42:59 - 172/03:36:05	Yes	3	Daily ATS load not uplinked, safing RTS executed; Event #41
98/172/02:45:15 - 172/03:36:05	Yes	4	Daily ATS load not uplinked, safing RTS executed; Event #41
98/172/02:45:20 - 172/03:37:08	Yes	5	Daily ATS load not uplinked, safing RTS executed; Event #41
98/172/02:45:19 - 172/03:42:39	Yes	6	Daily ATS load not uplinked, safing RTS executed; Event #41
99/003/21:20:21 - 006/21:59:36	No	3	Sun Acq & GSACE switch due to FDC violation; Anomaly #71
99/003/21:22:14 - 006/21:03:17	No	4	Sun Acq & GSACE switch due to FDC violation; Anomaly #71
99/003/21:22:25 - 006/21:55:09	No	5	Sun Acq & GSACE switch due to FDC violation; Anomaly #71
99/003/21:22:19 - 007/17:19:27	No	6	Sun Acq & GSACE switch due to FDC violation; Anomaly #71
99/003/21:48:58 - 004/22:39:47	Yes	1	Sun Acq & GSACE switch due to FDC violation; Anomaly #71

Table of Lost Data

Product	Srce	Frequency	Length	Granularity	Use and Comments
TRMM Ephemeris	FDF	Daily	10 days (8 in the future)	1 min	• Based on predicted burns. • Use by GSOC for ESI, CERES, and VIRS planning aid.
TRMM Ephemeris	FDF	Weekly	5 weeks	1 min	• Based on center of box. • FOT scheduling of planned activities. • Use by GSOC for ESI, CERES, and VIRS planning aid.
Planned Maneuver Command Files w/ EPV	FDF	2-10 days	two burns		• Times of maneuver burns used to generate Delta-V ATS • Formatted report (EPV) generated.
TRMM EPVs	FDF	Daily	2 days	1 per hour	• EPV updates and load generation.
TDRS EPVs	FDF	Monthly	1 Month	1 per two hours	
OBC Tables	FDF	As needed			• Earth sensor inputs, other table updates. • Processing/formatting on OST.
Local Oscillator Frequency (LOF) Report	FDF	Monthly			• FOT trend center frequencies • FOT calculate center frequency adjusts. • Received by email.
RTADS	MOC				• Real-time Attitude.
HUD	MOC				• Heads Up Display.
PSAT	FDF	Daily	7 days	1 per orbit	• Short term w/ burn plan factored in for command processing. • PR regions.
PSAT	FDF	Weekly	4 weeks	1 per orbit	• Long term for advanced mission planning. • MOC uses in timeline, UPS functions.
HGA Gimbal Angle/Range File	FDF	Weekly	4 weeks	1 min	• Not using, MOC S/W developers never gave ability
HGA Gimbal Angle/Range Data	FDF	Daily	7 days	1 min	
Solar Beta Angle	FDF	Daily	7 days	1 min	• Data includes ground track: long/lat/alt. • FOT uses correlate s/c anomalies to position. • Used as Planning aid. • Used for CERES/Yaw modeling
Solar Beta Angle	FDF	Weekly	4 weeks	1 min	
Solar Beta Angle	FDF	Quarterly	6 months	1 per 92 min	
TDRS UAV	FDF	Daily	7 days	N/A	• Short term with maneuvers factored in. • UPS processing, verify TDRS contacts after burns.
TDRS UAV	FDF	Weekly	4 weeks	N/A	• Long term center-of-box predict used for UPS scheduling. • UPS processing, select supports for forecast scheduling.

Table of MOC/FDF Products

Product	Srce	Frequency	Length	Granularity	Use and Comments
Special UAV	FDF	As needed	2-7 days	N/A	• +Y orientation for PR Antenna Pattern Measurements. • No orbit rate rotation for CERES Deep Space Calibration. • FOT verify continuous view of TDRS during maneuvers. • FOT selects supports if unable to recover attitude at pre-set time. • Use for Sun Acquisition views.
SLP Ephemeris (Solar, Lunar, Planetary)	FDF	Monthly	20 years	N/A	• Used by FDF GSOC Utility.
Time Conversion Coefficients File	FDF	Monthly	20 years	N/A	• Used by FDF GSOC Utility.
Sun/Moon Interference	MOC	Daily/Weekly	Length of Ephemeris	2 sec Execution Timestep	• Resolution of ESA anomalies. • ESA planning. • Generated by GSOC utility
		Weekly			
Sun/Moon Interference Notification	FDF	Weekly	35 days	N/A	• Notification of ESA blockage duration by FDF. • Received by email
VIRS planning aid	MOC	Daily/Weekly	7Days/4 Weeks	2 sec Execution Timestep	• When Moon is in VIRS space port. • When Sun is in field of view of the Solar Calibration door. • Sent to TSDIS.
CERES Azimuth/Elevation Angle	MOC	Daily/Weekly	7Days/4 Weeks	N/A	• FOT determination of CERES Solar Calibration times. • MOC will select appropriate Sun Azimuth angle based on FOT specified time (GSOC) and include in CERES command. • Used for scheduling solar avoidance and Solar Cals in certain modes.
Advanced Planning maneuver file	FDF	Weekly	5 weeks	each burn	• Coordinate burns w/ other operations. • Predicted burns displayed on Monthly Calendar/Timeline.
Daily Planning maneuver file	FDF	Daily	two maneuvers	N/A	• Keep FOT updated on maneuvers. • Received by email.
TDRS contact schedule	MOC	Daily/Weekly	1 week	N/A	• FDF uses to know contact schedule. • Received NCC schedule placed in Formats directory. • Sent to MSFC, TSDIS, and LaRC.
Attitude telemetry	MOC	As needed	each pass	N/A	• Used by FDF for computations.
		3 days/week	24 hours		• Attitude data sent to FDF by Formats
Yaw maneuver notification	FDF	Prior to Yaw	one maneuver	N/A	• Specifies time FOT plans to command the Yaw around.

Table of MOC/FDF Products (Continued)

Product	Srce	Frequency	Length	Granularity	Use and Comments
Post burn report	MOC	After each burn			• FOT analysis of burn. • FDF analysis to continue next burn planning. • MOC generates report during offline process of VC1 data.
Planned Maneuver Approval file	MOC	After Load gen prior to burn			• After FOT review of Maneuver command sheet, FOT directs MOC to send Planned Mvr. Approval file to FDF. • Contents echo the transmitted Planned Mvr Cmd File.

Table of MOC/FDF Products (Continued)

ACS

ID#	Description	Limit 1	Period 1	Action 1	Limit 2	Period 2	Action 2	Minimum Database Value	Maximum Database Value	Database Value
				Sensor/Actuator Failure						
0-2	Digital & analog IRU X, Y, Z values within a limit	10	500 ms	Redundant Gyro Axis	10	500 ms	Switch to ACE-B tlm & control			8.7266E-04 rad/s HiRate & LoRate
3-5	IRU A, B, C within a limit	5	500 ms	Switch out bad gyro						11 counts
6	Gyro A motor current	5	500 ms	Switch out gyro A				0.07 amps	0.23 amps	0.15 amps
7	Gyro B motor current	5	500 ms	Switch out gyro B				0.05 amps	0.19 amps	0.12 amps
8	Gyro C motor current	5	500 ms	Switch out gyro C				0.07 amps	0.23 amps	0.15 amps
9-14	MTB X, Y, Z Dipole/Cmd within limits (ACE A & B)	600	500 ms	100% on other MTB						40 Am^2
15	Deleted									
16-18	No TAM A change	3000	500 ms	Switch to TAM B and enable tests #19-21						2.0E-02 microT
19-21	No TAM B change	3000	500 ms	Switch to ACE-B tlm & control						2.0E-02 microT
22	Deleted									
23	YAW Update: DSS(A) Bad Counts	1	1 orbit (11280 cyles)	Notify Gnd and mark DSS A bad						10 bad counts
24	YAW Update: DSS(B) Bad Counts	1	1 orbit (11280 cyles)	Notify Gnd and mark DSS B bad						10 bad counts
25	YAW Update: DSS(A&B) Bad Counts	1	1 orbit (11280 cyles)	Mark ephemeris bad & goto Sun Acq						10 bad counts
26	Below CSS 1 value	11280	500 ms	Event message						0.021352 (unit-less)
27	Below CSS 2 value	11280	500 ms	Event message						0.021385 (unit-less)
28	Below CSS 3 value	11280	500 ms	Event message						0.021394 (unit-less)
29	Below CSS 4 value	11280	500 ms	Event message						0.020937 (unit-less)
30	Below CSS 5 value	11280	500 ms	Event message						0.021761 (unit-less)
31	Below CSS 6 value	11280	500 ms	Event message						0.021462 (unit-less)
32	Below CSS 7 value	11280	500 ms	Event message						0.021844 (unit-less)
33	Below CSS 8 value	11280	500 ms	Event message						0.021407 (unit-less)
34	Neg Diag Elem - Cov Matrix	1	500 ms	Goto Sun Acq						
35	Cov Matrix Diverging	1	500 ms	Goto Sun Acq					0, 1, 2, 3, 4, 5	0.010968 rad; 2.115E-10 rad^2/s^2
36	Adjusted Residual Tolerance	11280	500 ms	Goto Sun Acq						9 rad^2
37	Deleted									

ACS FDC Table (Continued)

ID#	Description	Limit 1	Period 1	Action 1	Limit 2	Period 2	Action 2	Minimum Database Value	Maximum Database Value	Database Value
38-41	RWA 1-4 Cmd/Tach Comparison	10	500 ms	Switch to ACE-B tlm & control	10	500 ms	If 4 wheel control, power OFF and goto 3 wheel control			0.14 Nm
42-45	RWA 1-4 speed	10	500 ms	Event message						5000 RPM
46-57	ESA values static	10	500 ms	Switch to ACE-B tlm & control	10	500 ms	Flag Quadrant as bad			1 count
58-61	ESA sector values not within tolerance	320	500 ms	Switch to ACE-B tlm & control	320	500 ms	Flag Quadrant as bad			
ACE Failure Corrections										
62	'A' in control & no 'B' data	3	500 ms	Switch control to ACE-A and disable switching to ACE-B						
63	'A' not in control & no 'B' data	3	500 ms	Switch control to ACE-A and disable switching to ACE-B						
64	'A' in control & 'B' in control	3	500 ms	Switch control to ACE-A and disable switching to ACE-B						
65	'A' not in control & 'B' not in control	3	500 ms	Switch to ACE-B tlm & control						
66	'A' not in control & 'B' in control	3	500 ms	Switch to ACE-B tlm & control						
67	No 'A' data & 'B' not in control	3	500 ms	Red CSS and ACE-B tlm & control						
68	No 'A' data & 'B' in control	3	500 ms	Red CSS and ACE-B tlm & control						
Cases Tested When ACE-B Control FDC Is Enabled										
69	Deleted									
70	'B' not in control	3	500 ms	Switch control to ACE-A and goto ACE-B Safehold						
ACS Controller Problem - Sun Acquisition Mode										
71	System Momentum not decreasing	360	5 sec	Event message						2.778E-03 Nms per 10 cycles
72	Sun acq timeout	7200	500 ms	Red CSS and ACE-B tlm & control	7200	500 ms	Goto controlling ACE Safehold			15 degrees
ACS Controller Problem - Earth Acquisition Mode										
73	Earth acq timeout	3600	500 ms	Switch to ACE-B tlm & control	3600	500 ms	Goto Sun Acq			1 degree
ACS Controller Problem - Yaw Acquisition Mode										
74	Yaw acq timeout	3600	500 ms	Switch to ACE-B tlm & control	3600	500 ms	Goto Sun Acq			2.5 degrees
ACS Controller Problem - Nominal Mission Mode										
75-77	Pitch, Roll, Yaw position error	160	500 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			0.0524 rad

ACS FDC Table (Continued)

ID#	Description	Limit 1	Period 1	Action 1	Limit 2	Period 2	Action 2	Minimum Database Value	Maximum Database Value	Database Value
78-80	High Pitch, Roll, Yaw Rate	160	500 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			0.001047 rad/sec
81-84	ESA 1-4 quadrant blocked	1920	500 ms	Event message	1920	500 ms	Goto Sun Acq			10.25 degrees
ACS Controller Problem - Yaw Maneuvers										
85-86	Pitch, Roll Position Error	160	500 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			0.0524 rad (3 deg)
87-88	High Pitch, Roll Rate	160	500 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			0.001047 rad/sec (0.06 deg/sec)
ACS Controller Problem - Thruster Modes										
89	X attitude error	3	125 ms	Thrusters off & exit ΔV disable reentry						11 deg
90	Y attitude error	3	125 ms	Thrusters off & exit ΔV disable reentry						7 deg
91	Z attitude error	3	125 ms	Thrusters off & exit ΔV disable reentry						7 deg
92	Body momentum X too high	3	125 ms	Thrusters off & exit ΔV disable reentry						30 Nms
93	Body momentum Y too high	3	125 ms	Thrusters off & exit ΔV disable reentry						45 Nms
94	Body momentum Z too high	3	125 ms	Thrusters off & exit ΔV disable reentry						40 Nms
95	System momentum not decreasing	3	125 ms	Thrusters off & exit ΔV disable reentry						N/A
ACS Controller Problem - CERES Calibration Modes										
96-98	High Roll, Pitch, Yaw error	160	125 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			3 degrees
99-101	High Roll, Pitch, Yaw rate	160	125 ms	Switch to ACE-B tlm & control	160	500 ms	Goto Sun Acq			0.046 deg/sec
System Problem										
102	Deleted									
103	High momentum X	320	500 ms	Switch to ACE-B tlm & control	320	500 ms	Goto Safehold & Close ISO valves			55 Nms
104	High momentum Y	320	500 ms	Switch to ACE-B tlm & control	320	500 ms	Goto Safehold & Close ISO valves			110 Nms
105	Hight momentum Z	320	500 ms	Switch to ACE-B tlm & control	320	500 ms	Goto Safehold & Close ISO valves			55 Nms
106	ACS in standby & neither ACE in control & Safehold	3	500 ms	Switch to controlling ACE Safehold						
107	HW/SW eclipse mismatch	130	500 ms	Event message						
108	Deleted									

ACS FDC Table (Continued)

ID#	Description	Limit 1	Period 1	Action 1	Limit 2	Period 2	Action 2	Minimum Database Value	Maximum Database Value	Database Value
Gimbal Solar Array Drive Electronics										
109	SA not at index in Sun Acq	1200	500 ms	Switch to controlling ACE Safehold						2 degrees
110-111	SA software stop violation	3	500 ms	Event message				-50 degrees	+50 degrees	N/A
112-113	SA not at commanded position	240	500 ms	RTS to swap GSACE & goto Sun Acq						12 degrees
114	GSACE not in closed loop mode	3	500 ms	RTS to swap GSACE & goto Sun Acq	3	500 ms	Switch to controlling ACE Safehold			
115	Loss of comm with GSACE	3	500 ms	RTS to swap GSACE & goto Sun Acq	3	500 ms	Switch to controlling ACE Safehold			
116	SA pot position error	3	500 ms	Event message						10 degrees
ACS Computer Interface Failure										
117	Deleted									
118	ACE detected to be in safehold	3	500 ms	ACS to standby mode						

Date	DOY	Maneuver Direction	Maneuver Time
1/14/1998	014	-X to +X	20:48:00
1/29/1998	029	+X to -X	23:30:00
2/27/1998	058	-X to +X	12:00:00
3/21/1998	080	+X to -X	00:28:00
4/11/1998	101	-X to +X	19:11:05
5/10/1998	130	+X to -X	01:24:00
5/25/1998	145	-X to +X	10:11:00
6/26/1998	177	+X to -X	11:52:27
7/10/1998	191	-X to +X	01:56:00
8/9/1998	221	+X to -X	21:10:54
8/28/1998	240	-X to +X	07:09:00
9/22/1998	265	+X to -X	15:13:05
10/17/1998	290	-X to +X	15:41:34
11/5/1998	309	+X to -X	01:38:09
12/5/1998	339	-X to +X	14:45:01
12/19/1998	353	+X to -X	00:18:17
1/19/1999	019	-X to +X	16:52:10
2/4/1999	035	+X to -X	12:19:57
3/4/1999	063	-X to +X	03:20:00
3/26/1999	085	+X to -X	14:51:27
4/16/1999	106	-X to +X	15:18:16
5/15/1999	135	+X to -X	12:46:25
5/30/1999	150	-X to +X	09:21:32

Table of Yaw Maneuvers (Jan 98 - June 99)

RCS

MVR #	DOY	L+ Days	DATE	MANEUVER TIMES	THR SET	FUEL LEFT (kg)	FUEL USED
1	333	2	29-Nov-97	17:58:00 - 17:58:10	5-8	889.8026	---------
2	334	3	30-Nov-97	15:11:00 - 15:11:10	5-8	889.5631	0.2395
3	335	4	1-Dec-97	15:03:00 - 15:03:10	1-4	889.3076	0.2555
4	337	6	3-Dec-97	19:35:00 - 19:36:00	5-8	887.9194	1.3882
5	338	7	4-Dec-97	20:07:00 - 20:10:00	5-8	883.722	4.1974
6	339	8	5-Dec-97	19:05:00 - 19:08:00 / 20:37:00 - 20:40:00	5-8	875.3373	8.3847
7	340	9	6-Dec-97	18:54:00 - 18:57:00 / 20:26:00 - 20:27:00	5-8	869.7533	5.584
8	341	10	7-Dec-97	17:43:37 - 17:44:58 / 19:28:41 - 19:29:50	5-8	866.2544	3.4989
9	353	22	19-Dec-97	18:08:46 - 18:09:43 / 18:57:43 - 18:58:05	5-8	864.4134	1.841
10	1	35	1-Jan-98	18:17:33 - 18:18:23 / 19:03:20 - 19:03:54	5-8	862.4729	1.9405
11	12	46	12-Jan-98	18:14:15 - 18:15:03 / 19:00:07 - 19:00:30	5-8	860.8126	1.6603
12	24	58	24-Jan-98	18:12:30 - 18:12:40 / (18:13:09 was expected)	1-4	860.5452	0.2674
13	25	59	25-Jan-98	18:44:09 - 18:44:42 / 19:29:50 - 19:30:18	1-4	859.0768	1.4684
14	35	69	4-Feb-98	17:48:57 - 17:49:46 / 18:34:49 - 18:35:14	5-8	857.3698	1.707
15	47	81	16-Feb-98	17:44:08 - 17:44:56 / 18:29:56 - 18:30:27	5-8	855.56	1.8098
16	56	90	25-Feb-98	18:22:42 - 18:23:33 / 19:08:38 - 19:09:02	5-8	853.8308	1.7292
17	65	99	6-Mar-98	18:31:52 - 18:32:34 / 19:17:38 - 19:18:09	1-4	852.1151	1.7157
18	74	108	15-Mar-98	17:44:31 - 17:45:19 / 18:29:22 - 18:29:40	1-4	850.5566	1.5585
19	80	114	21-Mar-98	18:20:46 - 18:21:33 / 19:07:36 - 19:08:01	5-8	848.8763	1.6803
20	87	121	28-Mar-98	17:55:16 - 17:56:09 / 18:41:09 - 18:41:36	5-8	847.0206	1.8557
21	94	128	4-Apr-98	17:34:45 - 17:35:22 / 18:20:29 - 18:21:00	5-8	845.4479	1.5727
22	100	134	10-Apr-98	16:59:32 - 17:00:19 / 17:45:24 - 17:45:43	5-8	843.9155	1.5324
23	106	140	16-Apr-98	16:04:22 - 16:05:08 / 16:50:11 - 16:50:40	1-4	842.1455	1.77
24	113	147	23-Apr-98	17:04:44 - 17:05:26 / 17:50:31 - 17:51:00	1-4	840.4783	1.6672
25	121	155	1-May-98	17:35:22 - 17:36:09 / 18:21:16 - 18:21:32	1-4	838.992	1.4863
26	127	161	7-May-98	16:38:48 - 16:39:36 / 17:24:44 - 17:25:06	1-4	837.3263	1.6657

27	135	169	15-May-98	16:27:56 - 16:28:45 / 17:13:47 - 17:14:14	5-8	835.5599	1.7664
28	143	177	23-May-98	16:38:26 - 16:39:04 / 17:24:13 - 17:24:39	5-8	834.0699	1.49
29	154	188	3-Jun-98	16:22:41 - 16:23:26 / 17:11:31 - 17:11:56	1-4	832.4231	1.6468
30	162	196	11-Jun-98	16:41:52 - 16:42:28 / 17:27:31 - 17:28:04	1-4	830.7698	1.6533
31	171	205	20-Jun-98	16:55:55 - 16:56:42 / 17:41:48 - 17:42:02	1-4	829.329	1.4408
32	180	214	29-Jun-98	17:02:44 - 17:03:36 / 17:48:37 - 17:49:03	5-8	827.2816	2.0474
33	188	222	7-Jul-98	17:10:10 - 17:10:56 / 17:55:58 - 17:56:30	5-8	825.4729	1.8087
34	197	231	16-Jul-98	17:41:36 - 17:42:35 / 18:30:37 - 18:31:03	1-4	823.4677	2.0052
35	206	240	25-Jul-98	17:29:57 - 17:30:33 / 18:16:44 - 18:17:06	1-4	822.0697	1.398
36	213	247	1-Aug-98	16:19:33 - 16:20:15 / 17:05:27 - 17:05:38	1-4	820.8078	1.2619
37	220	254	8-Aug-98	17:25:03 - 17:25:56 / 18:11:49 - 18:12:11	1-4	819.0338	1.774
38	227	261	15-Aug-98	16:46:22 - 16:47:07 / 17:32:09 - 17:32:33	5-8	817.4288	1.605
39	233	267	21-Aug-98	17:43:20 - 17:44:00 / 18:29:45 - 18:30:14	5-8	815.8397	1.5891

TRMM Delta-V Summary Through June 1999

MVR #	DOY	L+ Days	DATE	MANEUVER TIMES	THR SET	FUEL LEFT (kg)	FUEL USED
40	239	273	27-Aug-98	17:07:11 - 17:07:59 / 17:51:34 - 18:51:56	5-8	814.2218	1.6179
41	244	278	1-Sep-98	17:17:21 - 17:18:07 / 18:03:12 - 18:03:42	1-4	812.4243	1.7975
42	250	284	7-Sep-98	16:33:00 - 16:33:43 / 17:20:19 - 17:20:45	1-4	810.8043	1.62
43	255	289	12-Sep-98	17:20:50 - 17:21:27 / 18:05:00 - 18:05:18	1-4	809.4879	1.3164
44	261	295	18-Sep-98	16:23:13 - 16:24:00 / 17:08:43 - 17:09:02	1-4	807.9213	1.5666
45	265	299	22-Sep-98	16:26:51 - 16:27:24 / 17:11:08 - 17:11:25	5-8	806.7507	1.1706
46	269	303	26-Sep-98	16:18:10 - 16:18:51 / 17:03:58 - 17:04:20	5-8	805.294	1.4567
47	274	308	1-Oct-98	16:36:00 - 16:36:47 / 17:21:50 - 17:22:13	5-8	803.6689	1.6251
48	279	313	6-Oct-98	17:16:00 - 17:16:39 / 17:59:30 - 18:00:00	5-8	802.0837	1.5852
49	283	317	10-Oct-98	17:12:07 - 17:12:51 / 17:57:20 - 17:57:38	5-8	800.6407	1.443
50	288	322	15-Oct-98	17:41:06 - 17:41:51 / 18:27:54 - 18:28:22	5-8	798.9412	1.6995
51	292	326	19-Oct-98	17:25:00 - 17:25:41 / 18:10:50 - 18:11:16	1-4	797.359	1.5822
52	297	331	24-Oct-98	16:23:54 - 16:24:32 / 17:09:37 - 17:10:08	1-4	795.7318	1.6272
53	303	337	30-Oct-98	17:20:28 - 17:21:14 / 18:05:00 - 18:05:22	1-4	794.1177	1.6141
54	308	342	4-Nov-98	17:43:03 - 17:43:48 / 18:28:51 - 18:29:12	1-4	792.5484	1.5693
55	312	346	8-Nov-98	17:38:35 - 17:39:14 / 18:23:50 - 18:24:27	5-8	790.7869	1.7615
56	315	349	11-Nov-98	18:40:10 - 18:40:45 / 19:29:00 - 19:29:25	5-8	789.3828	1.4041
57	320	354	16-Nov-98	17:35:18 - 17:36:05 / 18:20:51 - 18:21:18	5-8	787.658	1.7248
58	326	360	22-Nov-98	17:01:00 - 17:01:42 / 17:48:20 - 17:48:45	5-8	786.0996	1.5584
59	331	365	27-Nov-98	17:34:10 - 17:35:00 / 18:19:20 - 18:19:49	5-8	784.278	1.8216
60	335	369	1-Dec-98	17:18:44 - 17:19:32 / 18:04:50 - 18:05:14	5-8	782.6096	1.6684
61	339	373	5-Dec-98	17:11:40 - 17:12:19 / 17:59:00 - 17:59:28	1-4	781.0183	1.5913
62	343	377	9-Dec-98	17:24:10 - 17:24:45 / 18:09:30 - 18:09:55	1-4	779.5814	1.4369
63	347	381	13-Dec-98	17:31:20 - 17:31:55 / 18:16:25 - 18:16:43	1-4	778.3043	1.2771
64	350	384	16-Dec-98	17:09:10 - 17:09:31 / 17:52:20 - 17:52:34	1-4	777.4578	0.8465

65	354	388	20-Dec-98	17:07:07 - 17:07:43 / 17:52:55 - 17:53:09	5-8	776.3343	1.1235
66	359	393	25-Dec-98	17:29:20 - 17:30:07 / 18:17:00 - 18:17:23	5-8	774.7105	1.6238
67	363	397	29-Dec-98	17:21:00 - 17:21:40 / 18:12:00 - 18:12:25	5-8	773.2048	1.5057
68	3	402	3-Jan-99	17:55:02 - 17:55:43 / N/A (Sun Acq Mode)	5-8	772.2572	0.9476
69	6	405	6-Jan-99	19:15:00 - 19:15:29 / 19:55:00 - 19:55:44	5-8	770.5641	1.6931
70	11	410	11-Jan-99	17:07:07 - 17:07:43 / 17:52:55 - 17:53:09	5-8	769.108	1.4561
71	16	415	16-Jan-99	16:48:07 - 16:48:46 / 17:35:00 - 17:35:24	5-8	767.6472	1.4608
72	20	419	20-Jan-99	18:13:00 - 18:13:34 / 18:58:27 - 18:58:53	1-4	766.2158	1.4314
73	24	423	24-Jan-99	16:46:29 - 16:47:07 / 17:32:25 - 17:32:49	1-4	764.7614	1.4544
74	29	428	29-Jan-99	17:21:48 - 17:22:30 / 18:07:32 - 18:07:55	1-4	763.2289	1.5325
75	33	432	2-Feb-99	15:49:00 - 15:49:32 / 16:37:00 - 16:37:12	1-4	762.1659	1.063
76	37	436	6-Feb-99	15:51:27 - 15:51:52 / 16:37:12 - 16:37:24	5-8	761.2995	0.8664
77	41	440	10-Feb-99	15:43:13 - 15:45:40 / 16:30:56 - 16:31:10	5-8	760.3376	0.9619
78	45	444	14-Feb-99	17:03:00 - 17:03:32 / 17:41:45 - 17:42:02	5-8	759.1943	1.1433

TRMM Delta-V Summary Through June 1999 (Continued)

MVR #	DOY	L+ Days	DATE	MANEUVER TIMES	THR SET	FUEL LEFT (kg)	FUEL USED
79	49	448	18-Feb-99	17:09:26 - 17:09:58 / 17:55:07 - 17:55:35	5-8	757.8043	1.39
80	53	452	22-Feb-99	15:52:53 - 15:53:40 / 16:40:00 - 16:40:24	5-8	756.1978	1.6065
81	57	456	26-Feb-99	16:09:00 - 16:09:33 / 16:53:46 - 16:54:08	5-8	754.9201	1.2777
82	61	460	2-Mar-99	15:51:58 - 15:52:34.000 / 16:37:49 - 16:37:59.750	5-8	753.8285	1.0916
83	65	464	6-Mar-99	15:47:44 - 15:48:15.000 / 16:33:28 - 16:33:53.625	1-4	752.4735	1.355
84	69	468	10-Mar-99	15:46:13 - 15:46:47.500 / 16:32:00 - 16:32:22.750	1-4	751.0963	1.3772
85	73	472	14-Mar-99	16:10:07 - 16:10:37.000 / 16:55:47 - 16:56:11.750	1-4	749.7891	1.3072
86	77	476	18-Mar-99	16:05:24 - 16:06:04.000 / 16:51:07 - 16:51:30.125	1-4	748.3021	1.487
87	81	480	22-Mar-99	16:04:30 - 16:05:15.000 / 16:50:00 - 16:50:15.500	1-4	746.8715	1.4306
88	86	485	27-Mar-99	16:22:35 - 16:23:19.625 / 17:08:24 - 17:08:45.375	5-8	745.3386	1.5329
89	92	491	2-Apr-99	17:01:02 - 17:01:48.000 / 17:46:52 - 17:47:17.500	5-8	743.6694	1.6692
90	96	495	6-Apr-99	17:02:46 - 17:03:15.625 / 17:48:30 - 17:48:50.000	5-8	742.5277	1.1417
91	100	499	10-Apr-99	15:39:49 - 15:40:28.000 / 16:25:36 - 16:25:55.000	5-8	741.1895	1.3382
92	104	503	14-Apr-99	15:48:25 - 15:49:03.000 / 16:34:13 - 16:34:38.500	5-8	739.7128	1.4767
93	109	508	19-Apr-99	16:04:32 - 16:05:15.625 / 16:50:22 - 16:50:47.125	1-4	738.0923	1.6205
94	115	514	25-Apr-99	15:10:25 - 15:11:04.375 / 15:56:14 - 15:56:37.250	1-4	736.6172	1.4751
95	122	521	2-May-99	15:17:31 - 15:18:08.000 / 16:03:13 - 16:03:47.000	1-4	734.9302	1.687
96	127	526	7-May-99	15:32:46 - 15:32:22.000 / 16:18:37 - 16:18:50.500	1-4	733.5251	1.4051
97	131	530	11-May-99	15:25:20 - 15:26:03.000 / 16:11:07 - 16:11:24.250	1-4	732.1008	1.4243
98	135	534	15-May-99	16:55:00 - 16:55:41.250 / 17:41:44 - 17:42:09.250	5-8	730.5395	1.5613
99	141	540	21-May-99	16:01:29 - 16:02:16.750 / 16:47:18 - 16:47:45.625	5-8	728.7955	1.744
100	147	546	27-May-99	15:28:23 - 15:29:01.250 / 16:14:09 - 16:14:36.000	5-8	727.3275	1.468
101	152	551	1-Jun-99	15:49:46 - 15:50:30.250 / 16:34:00 - 16:34:20.375	1-4	725.7903	1.5372
102	157	556	6-Jun-99	14:41:17 - 14:42:03:250 / 15:27:08 - 15:27:31.750	1-4	724.1322	1.6581

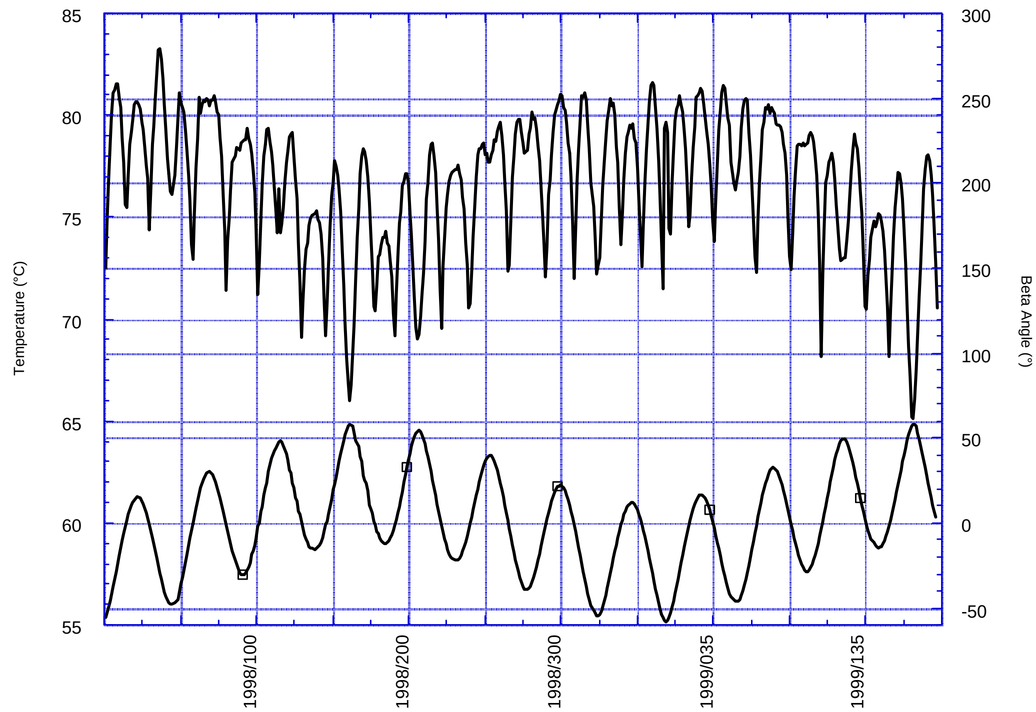
103	162	561	11-Jun-99	14:52:18 - 14:53:00.125 / 15:39:00 - 15:39:29.875	1-4	722.4312	1.701

TRMM Delta-V Summary Through June 1999 (Continued)

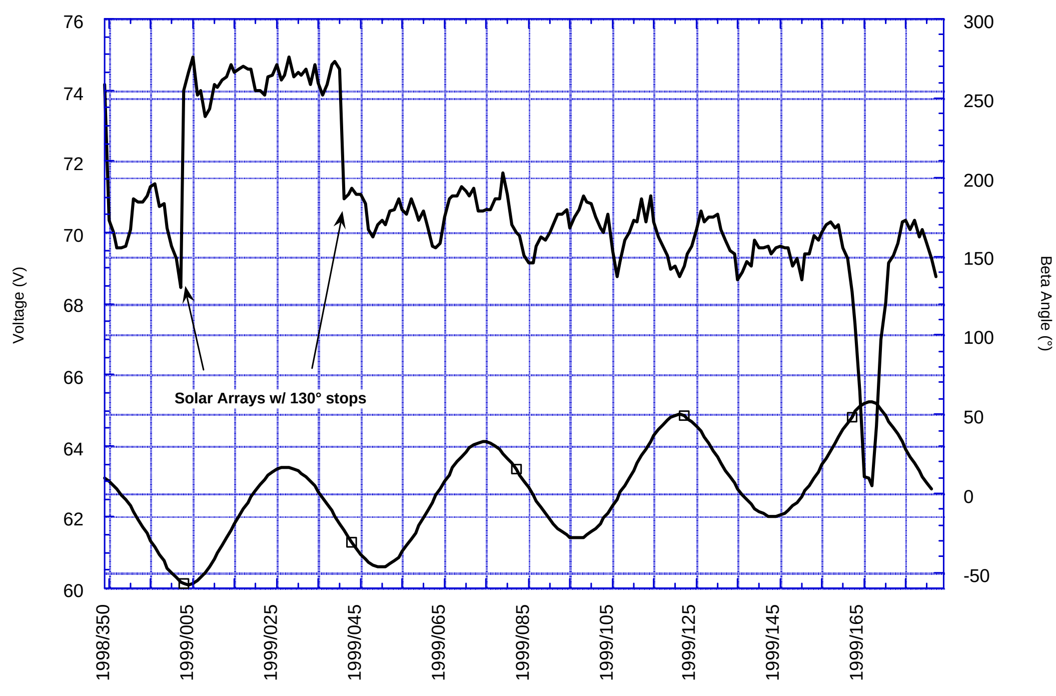
MVR #	DOY	L+ Days	DATE	MANEUVER TIMES	THR SET	FUEL LEFT (kg)	FUEL USED
104	167	566	16-Jun-99	16:06:28 - 16:07:00.000 / 16:52:10 - 16:52:36.500	1-4	721.0293	1.4019
105	172	571	21-Jun-99	16:05:59 - 16:06:37.125 / 16:53:15 - 16:53:29.875	1-4	719.7857	1.2436
106	177	576	26-Jun-99	14:52:18 - 14:53:06.500 / 15:38:09 - 15:38:27.000	1-4	718.2135	1.5722
107	181	580	30-Jun-99	14:50:48 - 14:51:25.625 / 15:36:36 - 15:36:56.125	1-4	716.8458	1.3677

TRMM Delta-V Summary Through June 1999 (Continued)

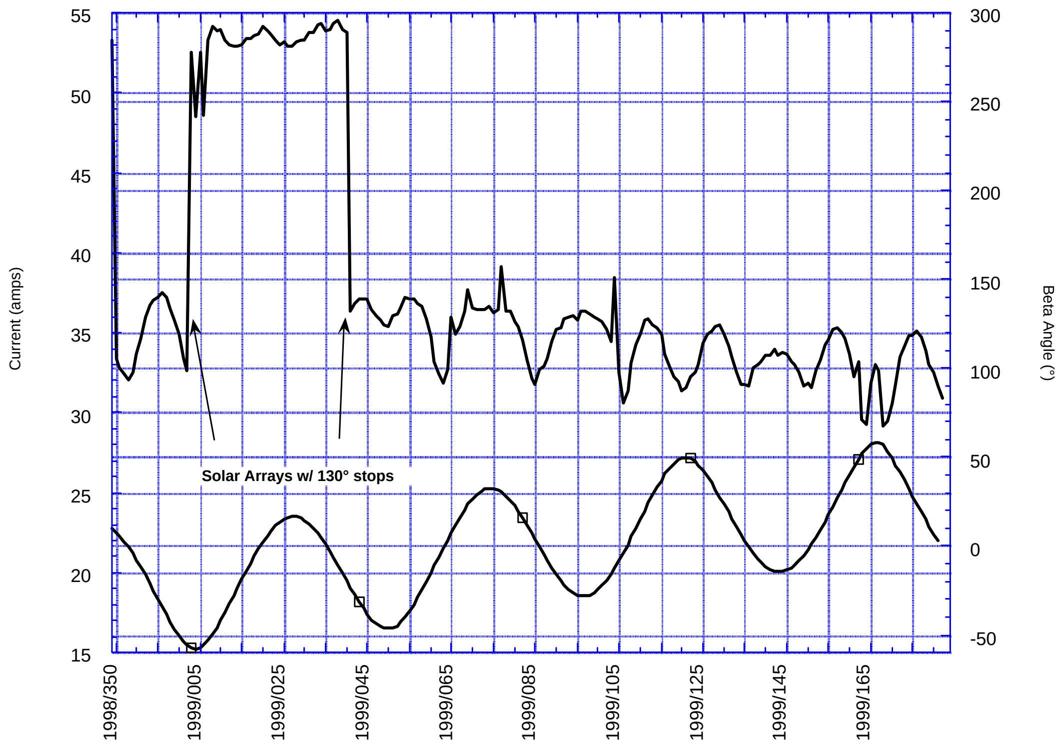
Power



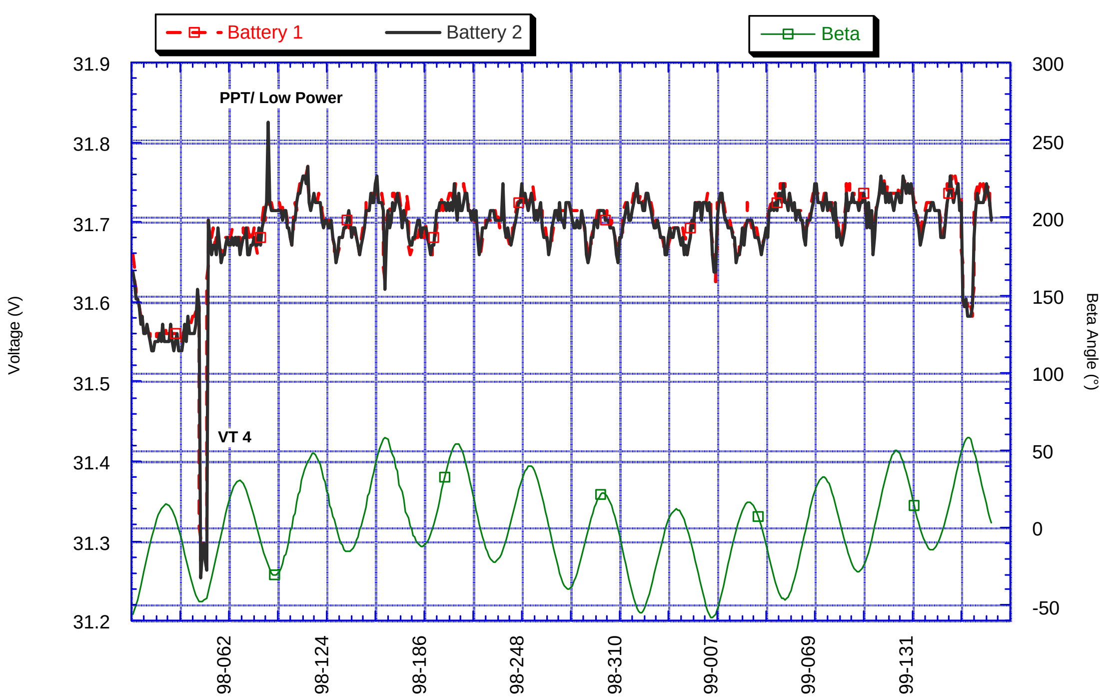
Solar Array -Y Inner Panel Temperature in Relation to Beta Angle



Solar Array Voltage Maximums in Relation to Beta Angle



Solar Array Current Maximums in Relation to Beta Angle



Battery Voltage Maximums in Relation to Beta Angle

Instruments Off/On

Table of Instrument Power Off/On Times

	Low Power		Sun Acquisition		Leonid Storm		GSACE Switch/Sun Acquisition	
	Off	On	Off	On	Off	On	Off	On
CERES	98/062/21:31:02	98/063/01:33:36	98/115/03:15:35	98/115/14:25:21				
LIS	98/062/21:30:48	98/063/01:06:56	98/115/03:15:31	98/115/09:18:49	98/321/15:47:59	98/322/00:52:12	99/003/21:29:41	99/006/21:57:26
PR	98/062/21:30:49	98/063/00:22:27	98/115/03:15:30	98/115/11:19:43	98/321/15:59:35	98/322/00:49:57	99/003/21:29:40	99/006/21:03:17
TMI	98/062/21:30:47	98/062/23:34:26	98/115/03:15:30	98/115/09:12:22	98/321/15:53:55	98/322/01:48:45	99/003/21:29:40	99/006/21:55:09
VIRS	98/062/21:30:49	98/063/00:54:33	98/115/03:15:30	98/115/12:32:17	98/321/15:52:15	98/322/01:34:03	99/003/21:29:40	99/005/23:49:02

Appendix G: Acronym List

Term	**Description**
A	Amperes
ACE	Attitude Control Electronics
ACS	Attitude Control System
ADPE	Automatic Data Processing Equipment
AETD	Applied Engineering Technology Directorate
AGO	Santiago (Chile)
Am^2	Amp-meters-squared
AOS	Acquisition of Signal
ARM	Atmospheric Radiation Measurement
ASCII	American Standard Code for Informational Interchange
ASYNC	Asynchronous
ATS	Absolute Time Sequences
BAPTA	Bearing and Power Transfer Assembly
bps	Bits per second
BED	Block Error Detector
C	Centigrade
C&DH	Command and Data Handling
C/D	Charge/Discharge
CCB	Configuration Change Board
CCL	Closed Circuit Loop
CCR	Configuration Change Request
CD	Conversion Device/Compact Disk
CERES	Clouds and the Earth’s Radiant Energy System
CES	Contact Entry Schedule
COMETS	Communication and Engineering Test Satellite (Japan)
CPT	Comprehensive Performance Testing
CPU	Central Processing Unit
CRC	Cyclic Redundancy Check
CRM	Continuous Risk Management
CSC	Communication System Controller
CSOC	Consolidated Space Operations Contract
CT	Crosstrack
DAA	Data Acquisition Assembly
DAAC	Distributed Active Archive Center

dB	Decibel
DC	Data Capture
DDF	Data Distribution Facility
dHz	DecaHertz
DKS	Desktop Key Set
DR	Discrepancy Report
DS	Data Storage (FDS task)
DSN	Deep Space Network
DSS	Digital Sun Sensor
DSS-16	Goldstone, California, 26-meter DSN station
DSS-46	Canberra, Australia, 26-meter DSN station
DTF-21	DSN testing facility at JPL
EEPROM	Electronically-Erasable Programmable Read-Only Memory
EOC	Earth Observation Center
EOD	End-of-Day
EOL	End-of-Life
EON	End-of-Night
EPV	Extended Precision Vector
ESA	Earth Sensor Assembly
FCIF	Frequency Conversion/IF
FDC	Failure Detection and Correction
FDF	Flight Dynamics Facility
FDS	Flight Data System
FEP	Front End Processor
FORMATS	FDF Orbital and Mission Aids Transformation System
FOT	Flight Operations Team
FR	Framer
FS	Frequency Standard
FSS	Fixed Satellite Service
FSW	Flight Software
FTP	File Transfer Protocol
GB	GigaBytes
GCMR	Ground Configuration Message Request
Ghz	GigaHertz
GMT	Greenwich Mean Time
GN	Ground Network

GSACE	Gimbal and Solar Array Control Electronics
GSFC	Goddard Space Flight Center
GSOC	Guide Star Prediction and Occultation
GTAS	Generic Trending and Analysis System
HGA	High Gain Antenna
HGAS	High Gain Antenna System
HP-UX	Hewlett Packard Unix System
HS	Health&Safety
HUD	Heads Up Display
Hz	Hertz
I&T	Integration and Test
IN	Interference Notice
INDOEX	Indian Ocean Experiment
IOP	Instrument Operation Procedure
IOT	Instrument Operations Team
IP	Internet Protocol
IPSDU	Instrument Power Switching and Distribution Unit
IRU	Inertial Reference Unit
ISO	International Organization of Standards
ISP	Instrument Support Platform
ITMM	IPSDU Thermistor Monitoring Module
ITU	International Telecommunications Union
K	Kelvin
Kbps	Kilobits per second
Kg	Kilogram
Km	Kilometer
L&IOC	Launch and In-Orbit Checkout
LAN	Local Area Network
LBS	Lower Bus Structure
LaRC	Langley Research Center
LIS	Lightning Imaging Sensor
LISP	Lower Instrument Support Platform
LNA	Low Noise Amplifier
LOF	Local Oscillator Frequency
LOP	Local Operating Procedure
LOS	Loss of Signal

LTS	Local TPOCC Switch
LZP	Level Zero Processed
MAR	Mission Analysis Room
Mbps	Megabits per second
MB	MegaBytes
MDM	Multiplexer/Demultiplexer
MOC	Mission Operations Center
MOCR	Mission Operations Change Request
MODNET	Mission Operations and Data Systems Directorate Operational/Development Network
MOI	Moment of Inertia
MOPSS	Mission Operations Planning and Scheduling System
MP	Mission Planner
MS	Memory Scrub
MSFC	Marshal Space Flight Center
MSR	Monthly Status Review
MTB	Magnetic Torquer Bar
mV	Millivolts
NASA	National Aeronautics and Space Administration
Nascom	NASA Communications Network
NASDA	National Space Development Agency (Japan)
NCC	Network Control Center
N-M	Newton-Meter
N-M-S	Newton-Meter-Seconds
OA	Operations Agreement
ODB	Operational Database
ORS	Offset Radiation Source
OSC	Operations Support Center
OST	On-board Computer Support Terminal
PA	Performance Analyst
Pacor	Packet Processor
PC	Personal Computer
PCA	Power Converter Assembly
PN	Pseudo-Random Noise
POT	Potentiometer
pps	pulses per second

PR	Precipitation Radar
PSAT	Predicted Site Acquisition Tables
psia	Pounds per square inch, absolute
PSIB	Power System Interface Box
PTP	Programmable Telemetry Processor
RAID	Redundant Arrays of Inexpensive Disks
RAM	Random Access Memory
RCCA	Root Cause and Correction Analysis
RCS	Reaction Control Subsystem
RDD	Range Data Delay
RF	Radio Frequency
RFI	Radio Frequency Interference
RH	Red High
ROM	Read-Only Memory
RPM	Revolutions per minute
RS	Reed-Solomon
RTADS	Real-Time Attitude Determination System
RTS	Relative time-tagged sequences
RWA	Reaction Wheel Assembly
RXTE	Rossi X-Ray Timing Explorer
s	Seconds
S/C	Spacecraft
SA	Solar Array
SAA	South Atlantic Anomaly
SB	Software Bus
ScaRaB	Scanner for Radiation Budget
SCAMA	Switching, Conferencing and Monitoring Arrangement
SCDP	System Control Data Processor
SDPF	Sensor Data Processing Facility
SDS	Spacecraft Data System
SE	Sustaining Engineering
SEU	Single Event Upset
SMEX	Small Explorer Program
SN	Space Network
SOC	State of Charge
SOTA	Special Operations and Testing Area

SPRU	Standard Power Regulator Unit
SSTC	Solid State Temperature Controllers
STDN	Space Tracking Data Network
STGT	Second TDRS Ground Terminal
STS	Space Transport System (Shuttle)
STTF	Spacecraft Test and Training Facility
TAM	Three-Axis Magnetometer
TC	Time Code (FDS task)
TCS	Thermal Control Subsystem
TCXO	Temperature Compensated Crystal Oscillator
TD7	Tracking and Data Relay Satellite 171
TDE	Tracking and Data Relay Satellite East
TDRS	Tracking and Data Relay Satellite
TDS	Tracking and Data Relay Satellite Spare
TDW	Tracking and Data Relay Satellite West
TIL	Technical Interface Letter
TMI	TRMM Microwave Imager
TO	Telemetry Output (FDS task)
TPOCC	Transportable Payload Operations Control Center
TRMM	Tropical Rainfall Measuring Mission
TSDIS	TRMM Science Data and Information System
TSM	Telemetry & Statistics Monitor/TPOCC Systems Managers
TSTOL	TPOCC Systems Test and Operations Language
UAV	User Antenna View
UISP	Upper Instrument Support Platform
UPD	User Performance Data
UPS	User Planning System/Uninterruptable Power Supply
USCCS	User Spacecraft Clock Calibration System
μT	MicroTesla
UTC	Universal Time Coordinated
UTCF	Universal Time Correlation Factor
V	Volts
V/T	Voltage/Temperature
VDS	Voice Distribution System
VIRS	Visible and InfraRed Scanner

VR	Virtual Recorder
W	Watt
WPS	Wallops
WS	Workstation
WSC	White Sands Complex
WSGT	White Sands Ground Terminal
XA	ACS 1773 Optical Bus
XI	Instrument 1773 Optical Bus
XP	Transponder
XS	Spacecraft 1773 Optical Bus
XT	X-Terminal
Y2K	Year 2000
YH	Yellow High (telemetry limit)
YL	Yellow Low (telemetry limit)